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(54) **SYSTEM FOR TESTING MARKUP
LANGUAGE APPLICATIONS ON A DEVICE**

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G06F 11/36 (2006.01)

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CPC **G06F 11/2294** (2013.01); **G06F 11/362**
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None
See application file for complete search history.

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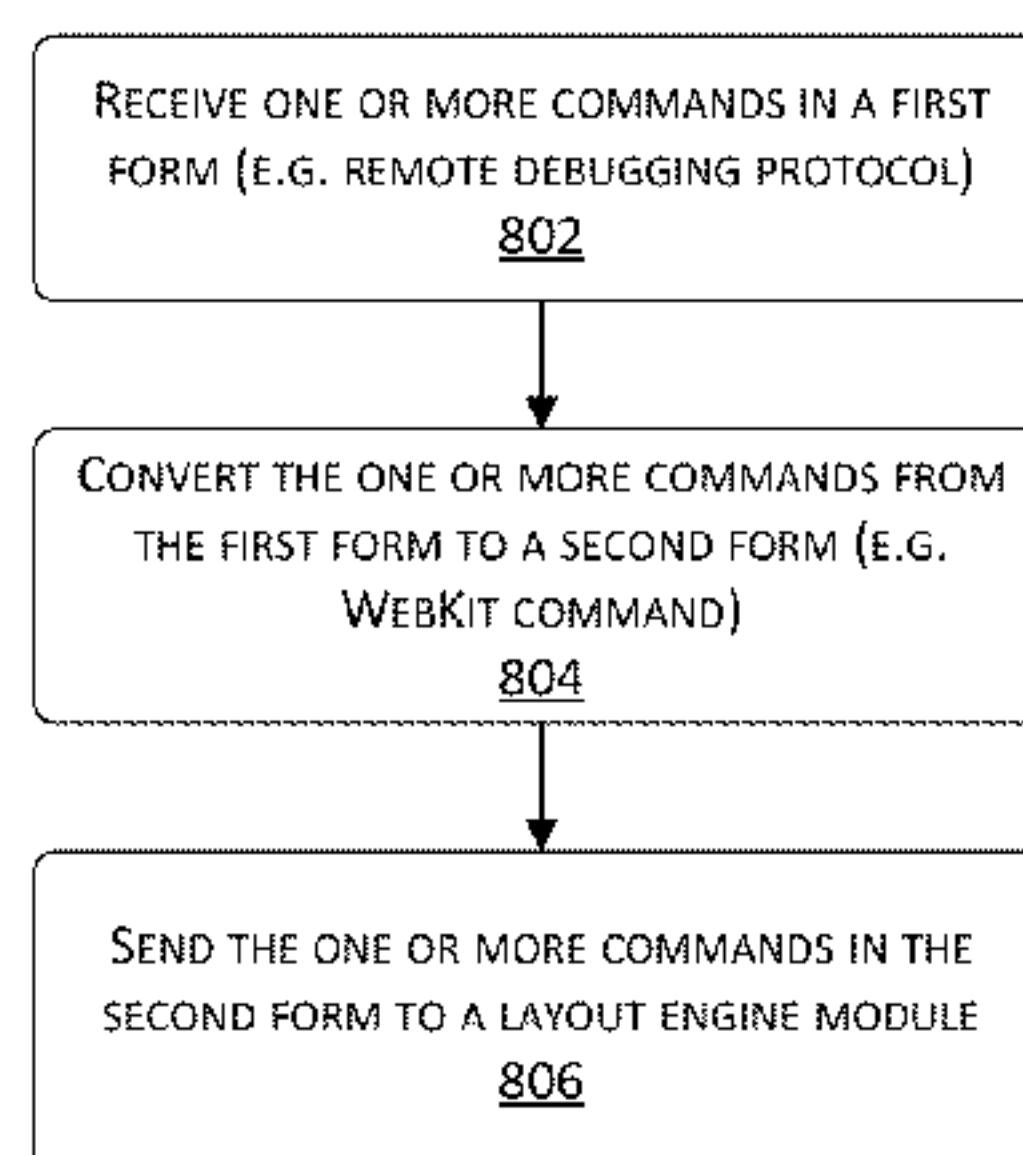
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(57) **ABSTRACT**

A system is described for testing markup language-based applications, such as a web page, executing on an external computing device. A development device executes development tool modules which may include a proxy module and a driver module. The proxy module enables communication between one or more modules which execute on the development device and one or more embedded test tools on the computing device. The driver module provides a command line interface to facilitate automated testing, and generates commands appropriate to the use of the embedded test tools and may use the proxy module to communicate with the computing device. Using the proxy module, the driver module, or both, a developer is able to test and interact with a markup language application executing on the computing device with a variety of development modules.

20 Claims, 9 Drawing Sheets

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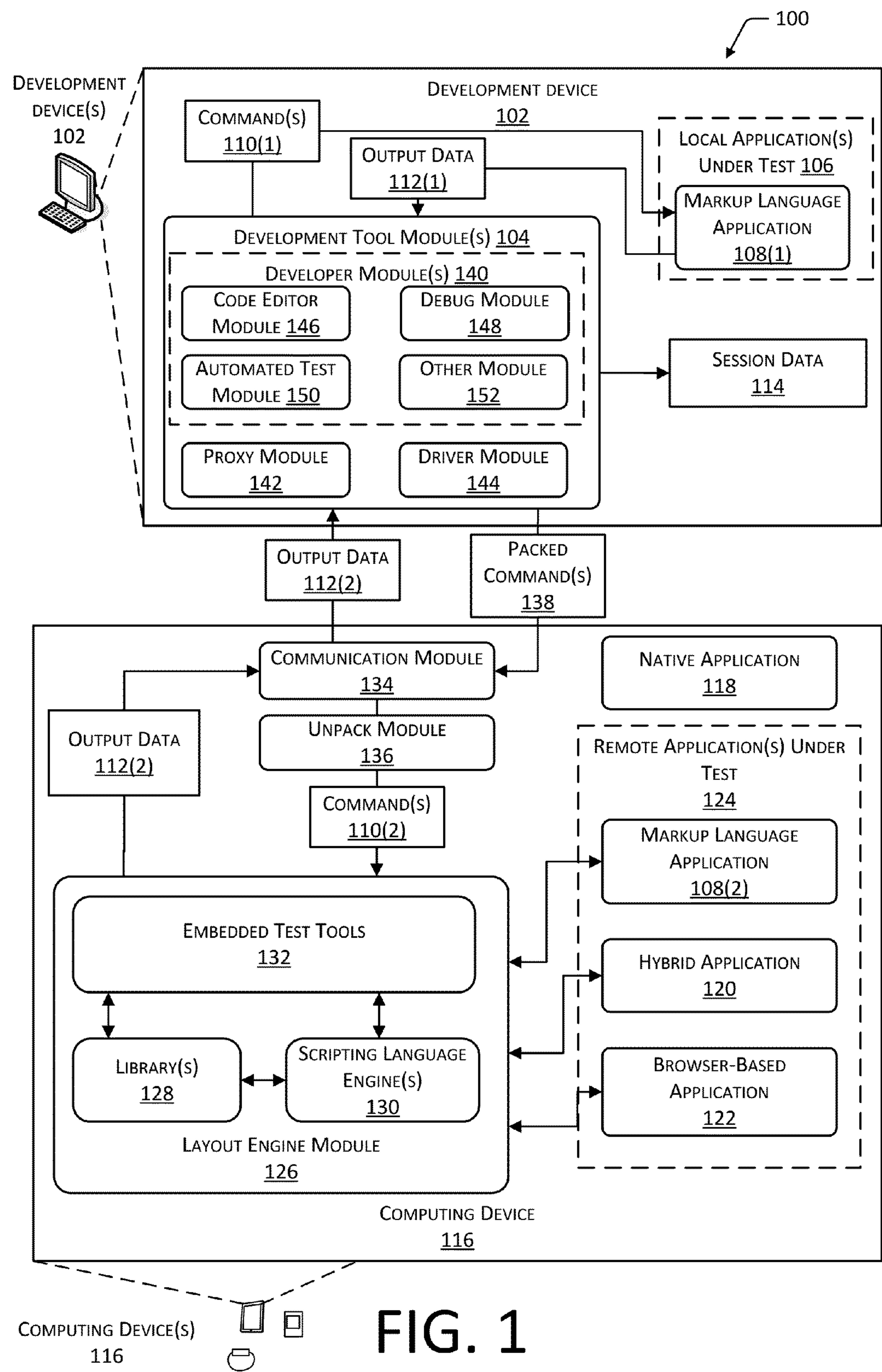


FIG. 1

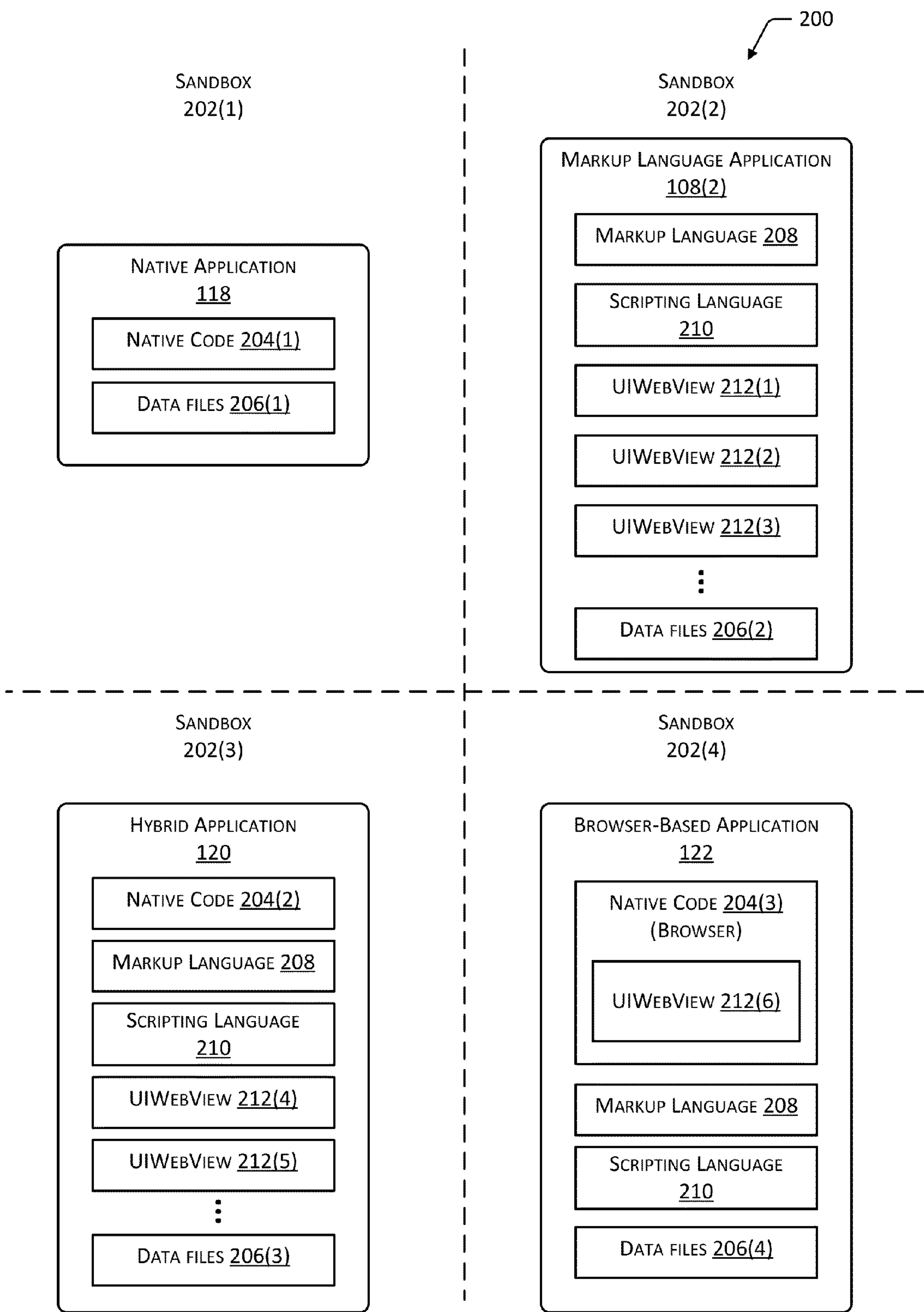


FIG. 2

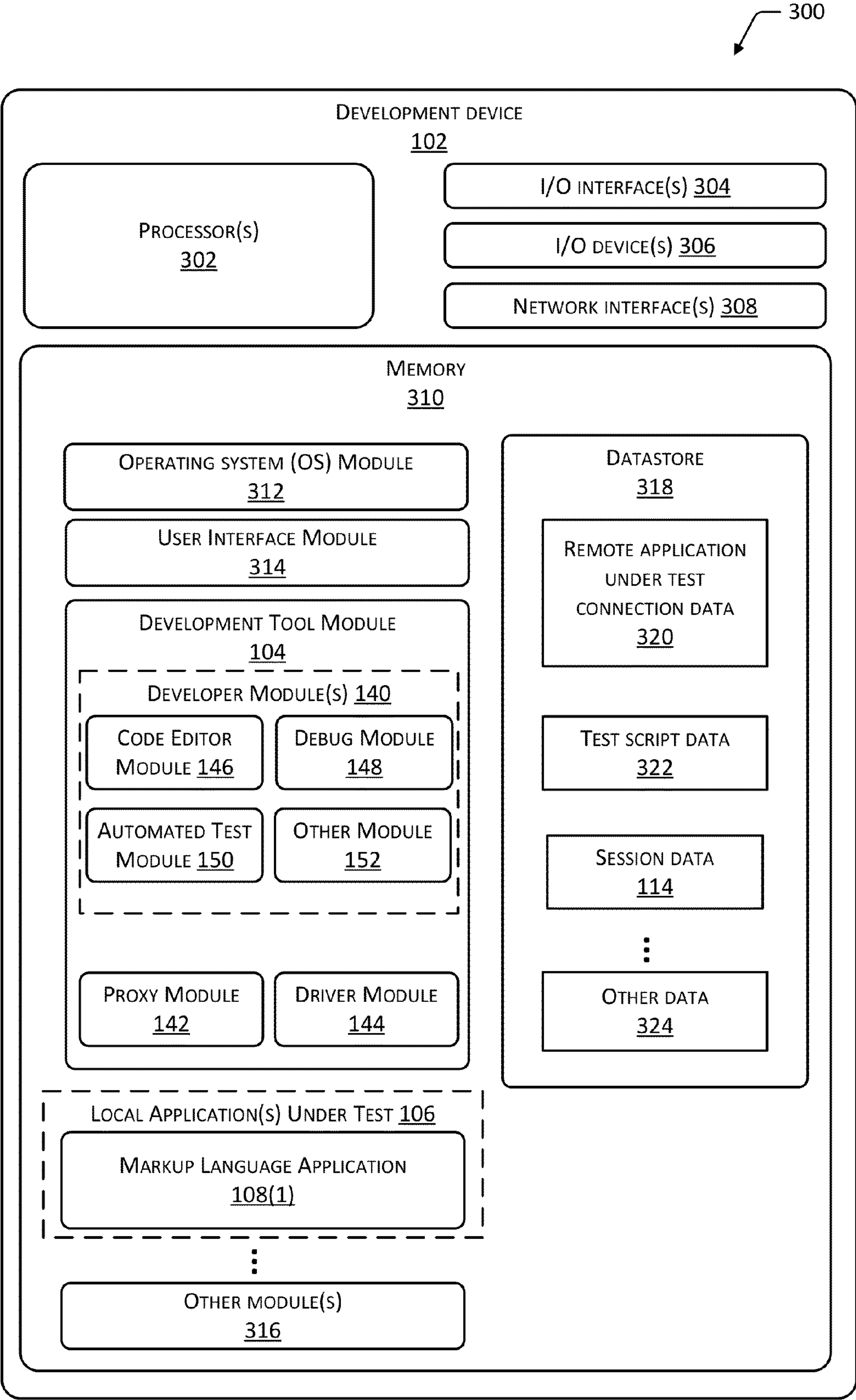


FIG. 3

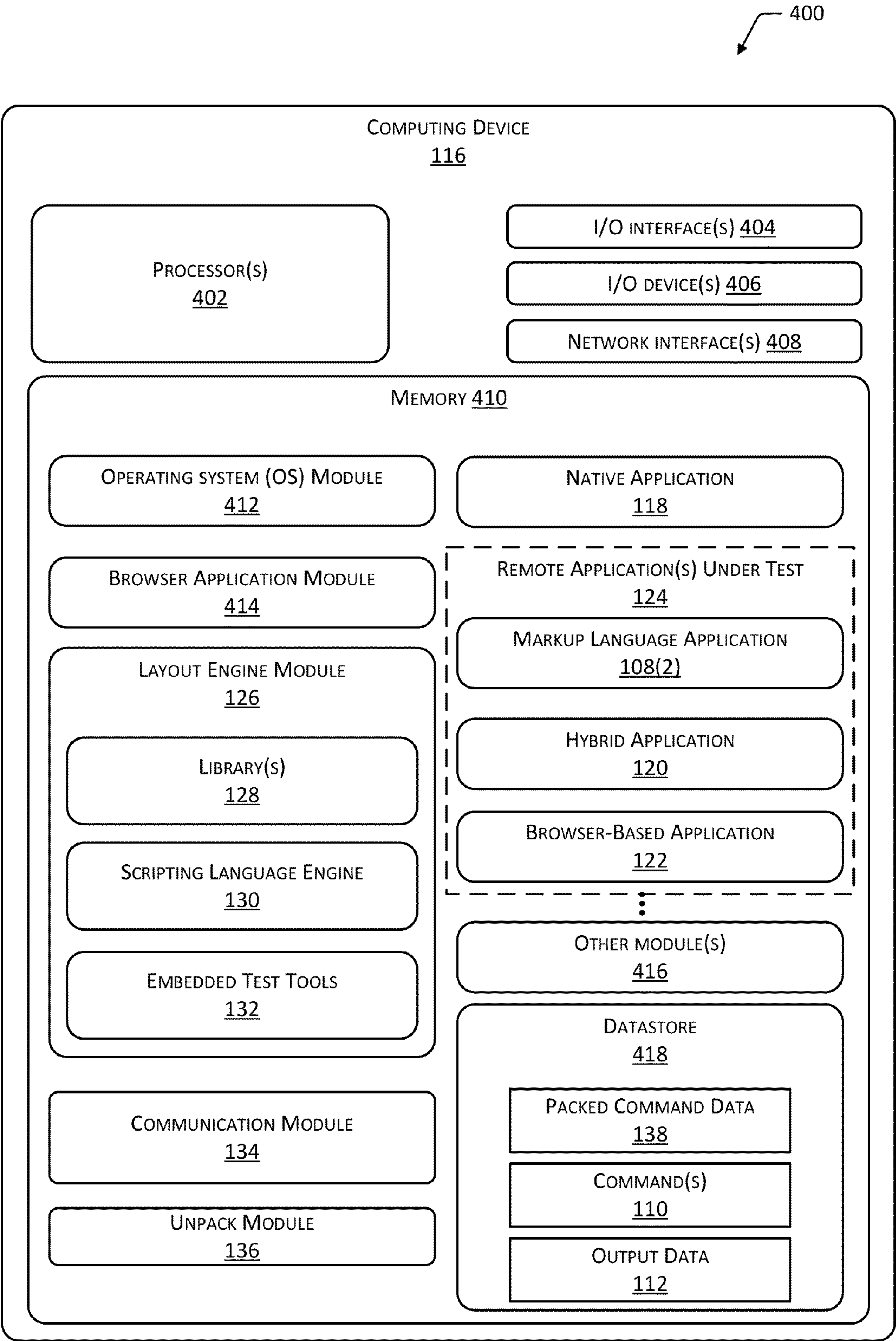


FIG. 4

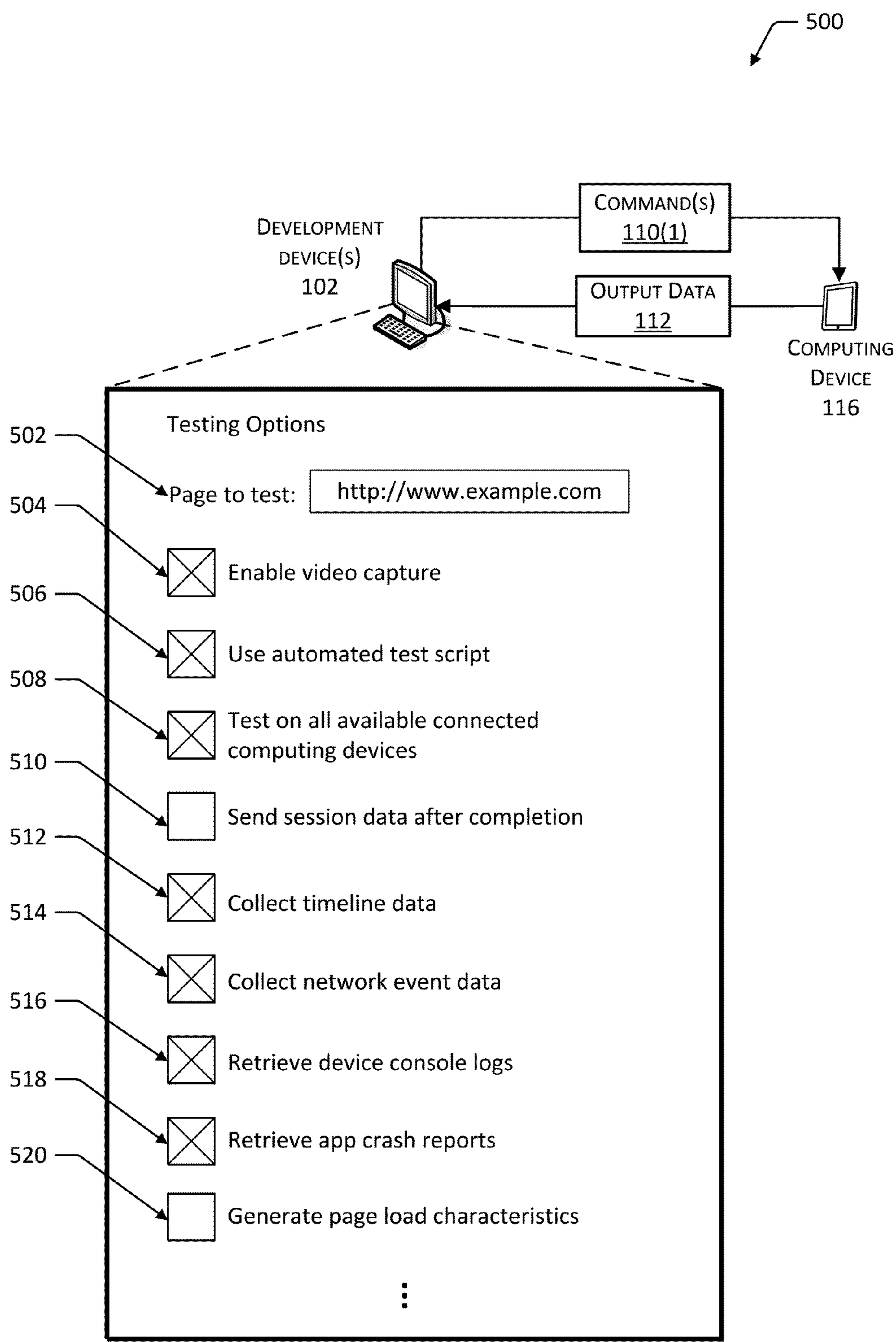


FIG. 5

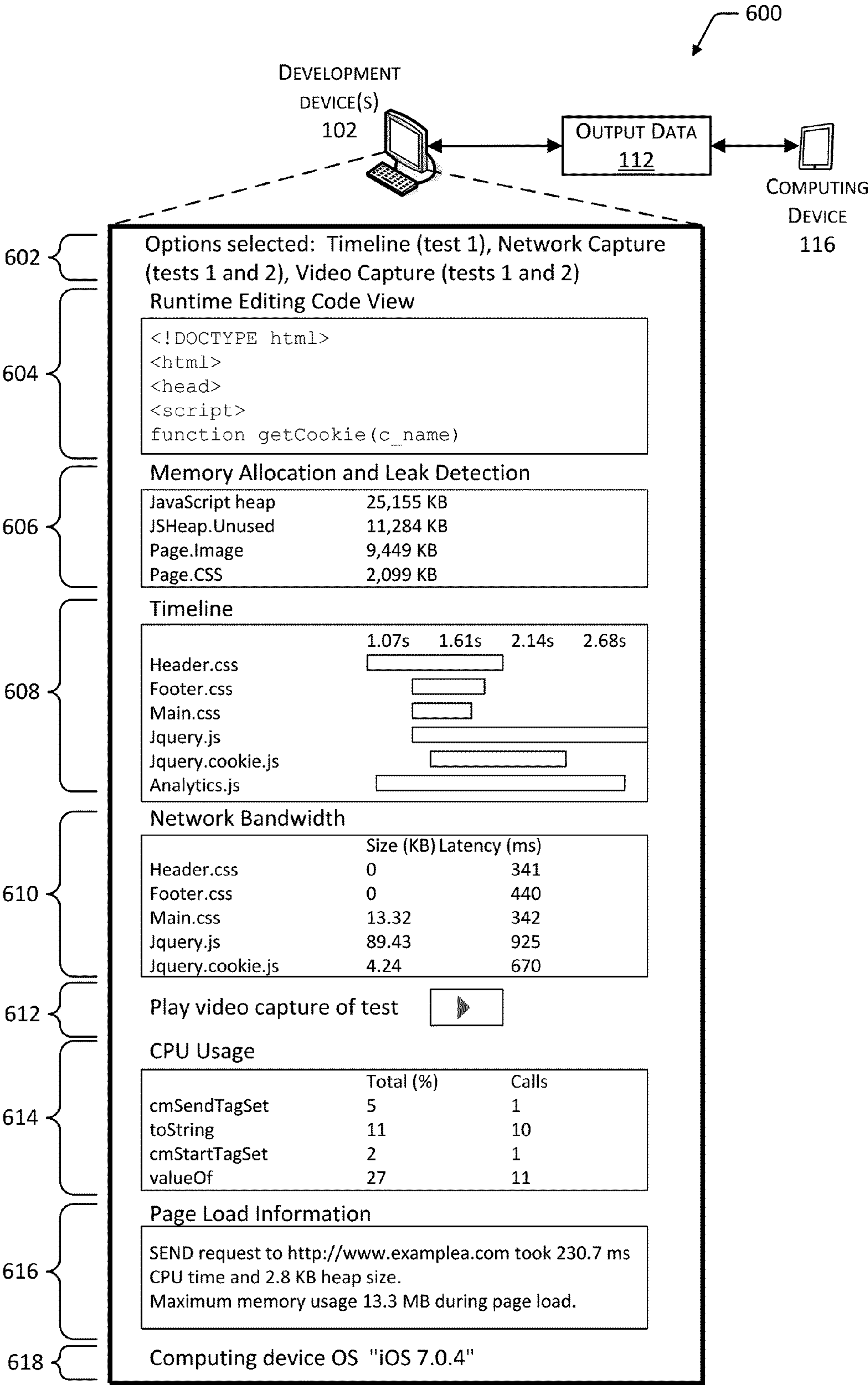


FIG. 6

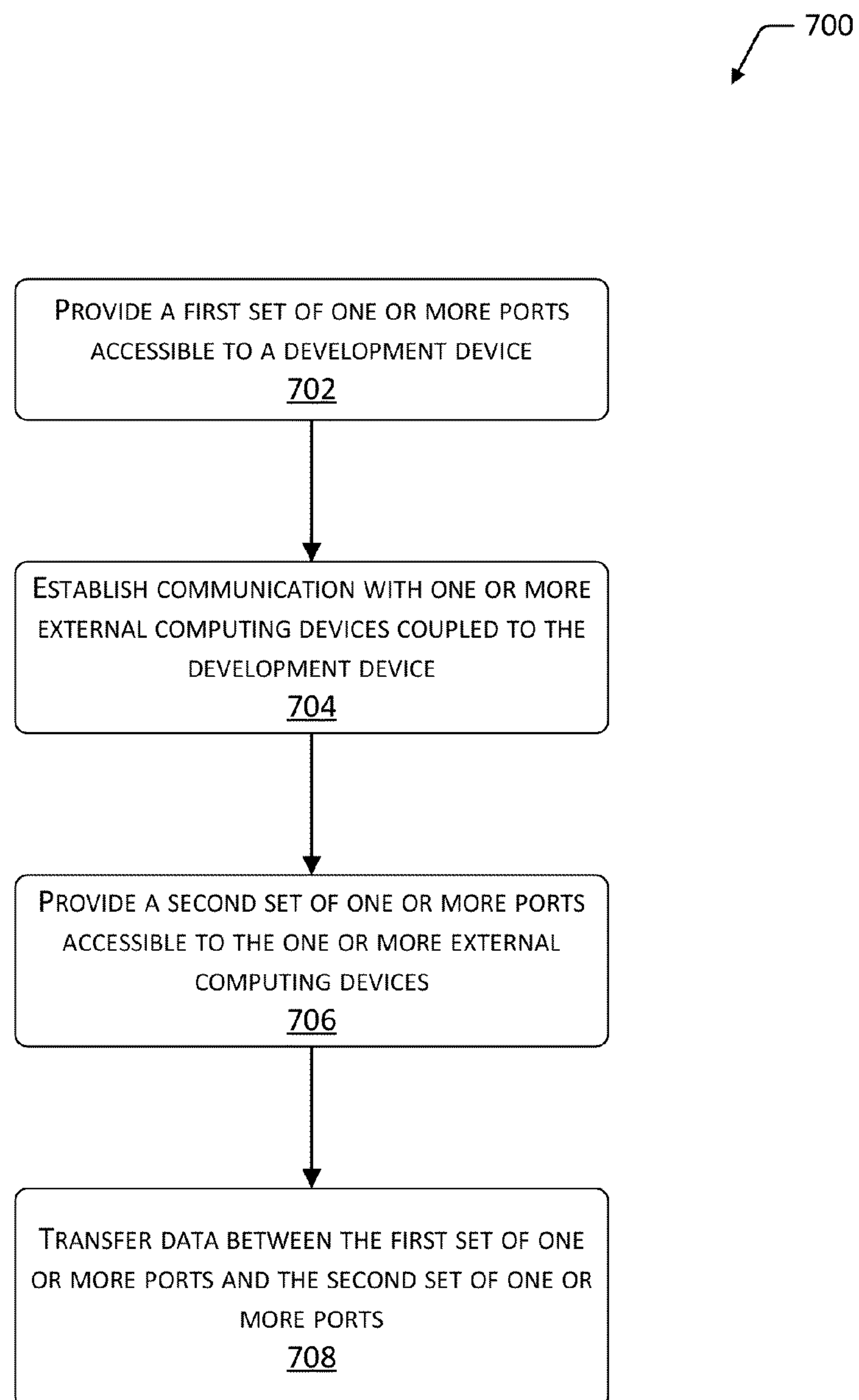


FIG. 7

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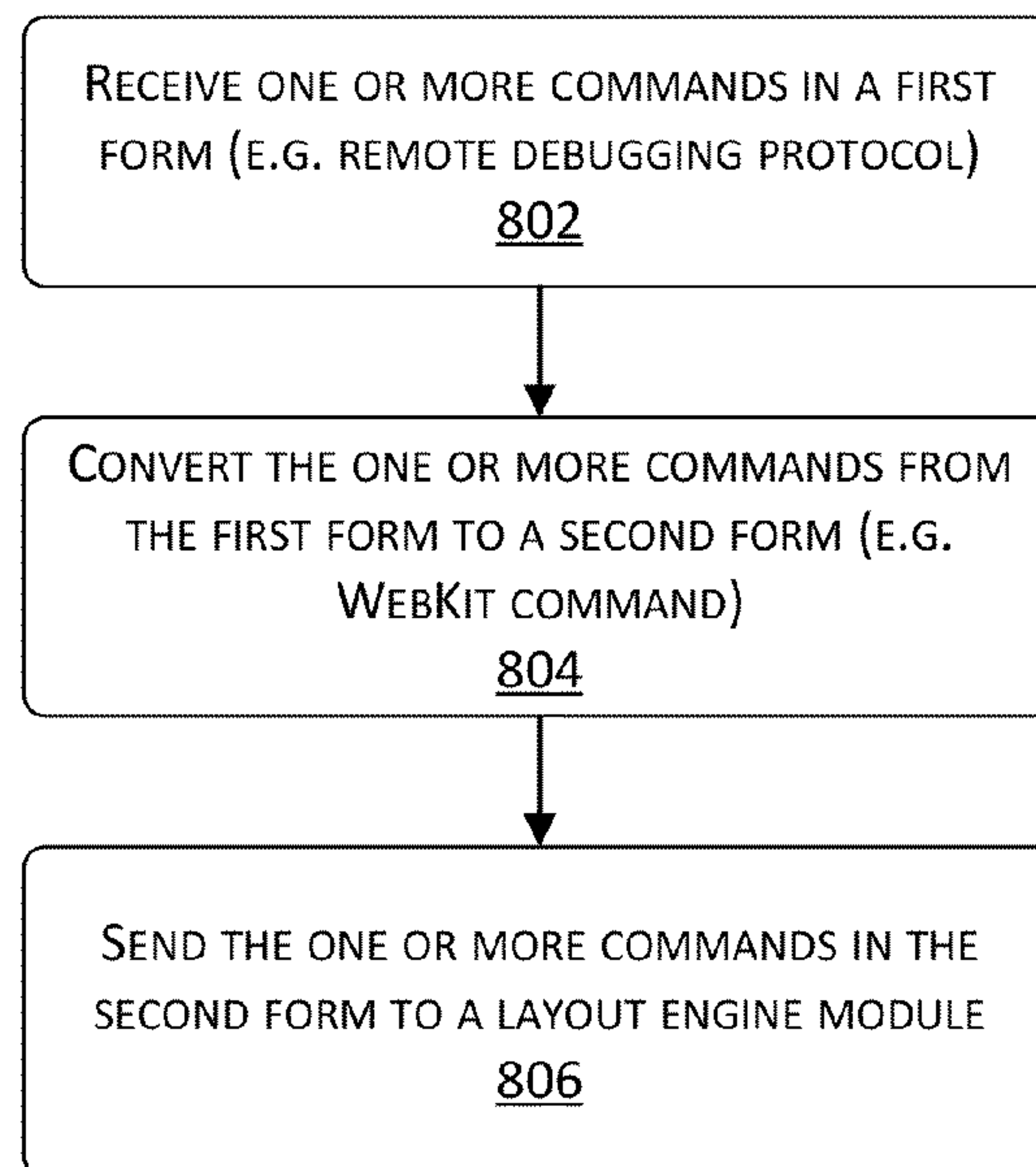
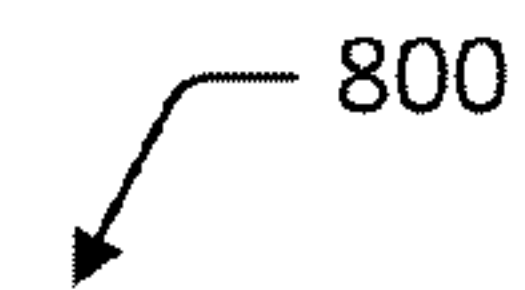


FIG. 8

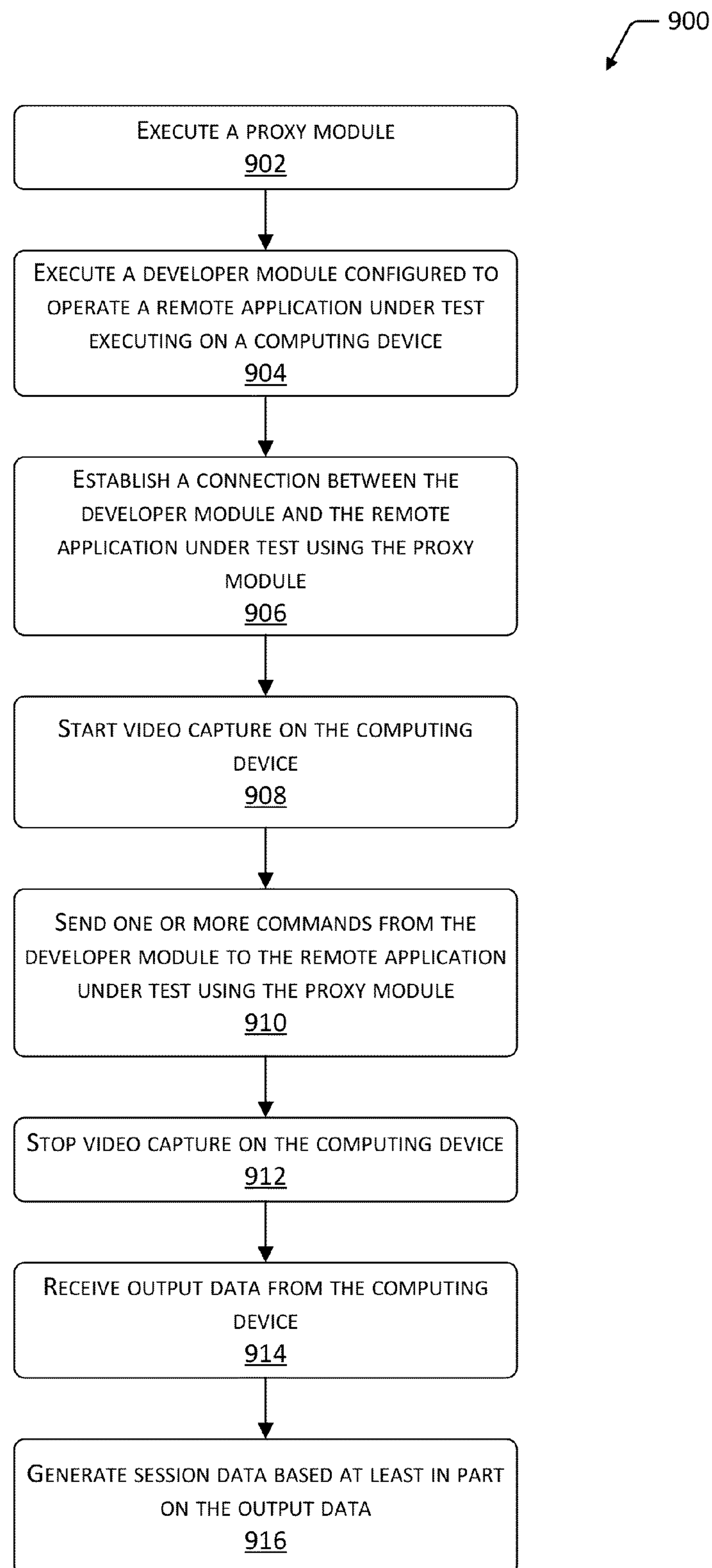


FIG. 9

SYSTEM FOR TESTING MARKUP LANGUAGE APPLICATIONS ON A DEVICE

BACKGROUND

With the growing popularity of computing devices, there is an increasing demand for applications, or apps, to run on such devices. These devices may include smartphones, tablet computers, televisions, set-top boxes, wearable devices, in-vehicle computer systems, home entertainment systems, embedded devices, and so forth. To satisfy this demand, programmers are constantly building, testing, and maintaining applications. Testing of these applications is useful for quality assurance to find and correct errors.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 depicts an environment having a development device for testing markup language applications executing on a remote computing device.

FIG. 2 illustrates different types of applications available for execution on the computing device, including those which use markup language.

FIG. 3 depicts a block diagram of the development device configured to perform operations for testing markup language applications.

FIG. 4 depicts a block diagram of the computing device configured to perform operations for testing markup language applications.

FIG. 5 depicts a user interface of testing options which may be selected by a developer for testing.

FIG. 6 depicts a user interface of testing results from the markup language application executing on the remote computing device.

FIG. 7 depicts a flow diagram of a process of a proxy module operating on a development device during debugging.

FIG. 8 depicts a flow diagram of a driver module converting commands from a first form to a second form.

FIG. 9 depicts a flow diagram of debugging a markup language application using the proxy module.

Certain implementations and embodiments will now be described more fully below with reference to the accompanying figures, in which various aspects are shown. However, various aspects may be implemented in many different forms and should not be construed as limited to the implementations set forth herein. Like numbers refer to like elements throughout.

INCORPORATION BY REFERENCE

The following applications are incorporated by reference.

U.S. patent application Ser. No. 13/619,867, filed on Sep. 14, 2012, titled “Remote Control of a Mobile Device” to Manish Lachwani, et al. is incorporated by reference into this disclosure.

U.S. patent application Ser. No. 13/680,671, filed on Nov. 19, 2012, titled “Configurable Network Virtualization” to Manish Lachwani, et al. is incorporated by reference into this disclosure.

U.S. patent application Ser. No. 13/631,919, filed on Sep. 29, 2012, titled “Application Validation Through Object Level Hierarchy Analysis” to Manish Lachwani, et al. is incorporated by reference into this disclosure.

U.S. patent application Ser. No. 13/655,667, filed on Oct. 19, 2012, titled “Application Auditing Through Object Level

Code Inspection” to Manish Lachwani, et al. is incorporated by reference into this disclosure.

U.S. patent application Ser. No. 13/721,632, filed on Dec. 20, 2012, titled “System For Testing Markup Language Applications” to Manish Lachwani, et al. is incorporated by reference into this disclosure.

U.S. patent application Ser. No. 13/741,989, filed on Jan. 15, 2013, titled “Application Testing System With Application Programming Interface” to Manish Lachwani, et al. is incorporated by reference into this disclosure.

U.S. patent application Ser. No. 13/862,240, filed on Apr. 12, 2013, titled “Test Automation API For Host Devices” to Manish Lachwani, et al. is incorporated by reference into this disclosure.

U.S. patent application Ser. No. 13/868,560, filed on Apr. 23, 2013, titled “Test Script Generation” to Manish Lachwani, et al. is incorporated by reference into this disclosure.

U.S. patent application Ser. No. 13/962,662, filed on Aug. 8, 2013, titled “Application Testing System” to Manish Lachwani, et al. is incorporated by reference into this disclosure.

U.S. patent application Ser. No. 14/050,071, filed on Oct. 9, 2013, titled “Performance Data Collection” to Manish Lachwani, et al. is incorporated by reference into this disclosure.

DETAILED DESCRIPTION

A wide variety of applications or apps are developed for execution on computing devices including smartphones, tablet computers, televisions, set-top boxes, wearable devices, in-vehicle computer systems, home entertainment systems, and so forth. Some of these devices are mobile devices, in that they are portable from one location to another.

There is an increasing demand for software developers to build applications, or apps, to run on such devices. Software developers build, test, and maintain applications using a variety of development tools. Testing provides many benefits including finding and correcting errors, improving performance, and so forth. Testing may include observing processor usage, observing memory allocation, programmatic debugging, determining usability, validating functionality, and so forth.

Different types of applications may be available for use on the computing devices. These include native applications, markup language applications, hybrid applications, and browser-based applications. Native applications are those which are written and compiled for execution on the particular device. For example, native applications may be written in a programming language such as C++ or Objective C and compiled into native code such as a binary executable for use on the device. Markup language applications include one or more instructions in a markup language which may be rendered by a layout engine and one or more instructions in a scripting language which may be interpreted by a scripting language engine during execution. For example, a hypertext markup language (“HTML”) version 5 (or higher) markup language application may include HTML, cascading style sheets (“CSS”), and JavaScript. In some implementations the markup language application may have multiple instances of the UIWebView class references. Hybrid applications include native code and markup language application portions. Browser-based applications are processed within a web browser application and are limited in execution. The browser-based applications may have one or more UIWebView instances.

Markup language applications confer several advantages including, in particular, ease of deployment across different

devices with no adjustment or minimal adjustment. For example, a markup language application for a smartphone from one manufacturer may also be executed on an in-vehicle system. In comparison, a native application may need to be re-coded, recompiled, and so forth to operate on different platforms. The platforms may be distinguished by different processors, operating systems, or combinations thereof. In some implementations, the markup language application may be provided as one or more web pages. For example, the markup language application may comprise the set of HTML5, CSS, JavaScript, and so forth which may be accessible by way of a network address. The network address may comprise a uniform resource locator (URL), uniform resource identifier (URI), internet protocol address, and so forth.

Traditional testing systems have lacked the ability to provide development tools for testing for markup language applications executing on computing devices. Software developers (developers) have had to rely on cumbersome methods for testing, including insertion of debug code, use of simulators, and so forth. The insertion of debug code, such as found in a software development kit (“SDK”), or manual breakpoints requires ongoing editing and adjustment of the code, and may result in incorrect or missed information. Likewise, the simulators lack the full fidelity provided by execution on the actual computing device.

Furthermore, developers may wish to use a particular tool with which they are more familiar, or which includes additional functionality, but which the computing device which will be executing the application to be tested may not natively support the particular tool. For example, a developer may prefer the set of features and interface associated with the Chrome™ Development Tools, also known as “DevTools” as promulgated by Google Inc. of Mountain View, Calif. Traditionally, the developer has been unable to use these Chrome™ DevTools to debug a markup language application which is executing on a computing device which is executing the iOS® operating system from Apple Corp. of Cupertino, Calif. Instead, the developer would need to use those tools specifically provided by Apple Corp., such as the Safari® Inspector to debug a markup language application executing on the iOS® operating system. As a result, developers may be frustrated in their development efforts.

This disclosure describes embodiments of systems and methods for testing markup language applications executing on an actual computing device, a simulation of a computing device, or both. A development device such as a desktop computer may execute one or more development tools such as debuggers, memory debuggers, and so forth. These development tools may be used to test markup language applications which are either local to the development device or which are remote, such as those executing on the computing device. In one implementation the development tools may include the Safari® Inspector as developed by Apple Corp. of Cupertino, Calif., Chrome™ Developer Tools as developed by Google Inc. of Mountain View, Calif., and so forth.

A proxy module is configured to provide communication between the development tools of the development device and embedded test tools which are present on the computing device. The proxy module allows for the use of the development tools to interact with an application under test and the modules which support execution thereof. These embedded test tools may be incorporated into other modules, such as a layout engine module. The layout engine module is configured to execute an application or portion thereof which uses a markup language, such as hypertext markup language (HTML) version 5 or higher. In one implementation the lay-

out engine module may comprise WebKit® as promulgated by Apple Corp. or others through an open source development model.

In some implementations the proxy module may be configured to provide an interface with one or more ports which is WebSocket-compatible. For example, the proxy module may provide a first set of one or more WebSockets which are available to communicate with the developer tools, and a second set of one or more WebSockets which are available to communicate with services or modules executing on the computing device. In some implementations, the WebSocket protocol may be compliant with the Internet Engineering Task Force (IETF) Request For Comments (RFC) 6455, also known as RFC 6455.

In some implementations a developer may choose to use development tools which may be otherwise incompatible with the layout engine module or the embedded test tools. For example, a developer may choose to use the Google Chrome™ DevTools to debug a web site which is rendered in the Mobile Safari® browser executing on the computing device running the Apple iOS® operating system. In this example, the Google Chrome™ DevTools use the Google Inc. remote debugging protocol, however the WebKit® portion of the layout engine module may be unable to process inputs made using the remote debugging protocol.

A driver module may be employed to accept one or more commands in a first form and output one or more commands in a second form. Continuing the earlier example, the driver module may accept remote debugging protocol inputs from DevTools, command line inputs, and so forth, and provide outputs which are compatible with WebKit®. The driver module may be configured to accept manual inputs, scripted input, programmatically generated inputs, and so forth. For example, the driver module may be configured to accept, as input, commands included in test script data. In some implementations the driver module may use WebSockets to exchange information with other modules such as the developer tools, proxy module, and so forth.

With the proxy module and the driver module, developers may use a wide variety of tools to develop applications which incorporate markup language. As described above, a developer may use the Chrome™ DevTools to debug a web page as rendered by the Apple Mobile Safari® browser executing on the iOS® operating system.

The techniques and modules described above may be performed using a computing device which is in the secured configuration, such as a default operating system which has not been “jailbroken”. In this secured configuration access to the operating system on the computing device, file system, and so forth may be restricted.

By eliminating the need for insertion of debugging code and the associated effort involved, overall productivity and effectiveness of the software development effort is improved. For example by using the proxy module, the developer may debug a markup language application on the computing device using existing on-board (previously loaded) embedded test tools, such as the Apple Safari® web inspector “com.apple.webinspectord”. Finally, the use of the actual computing device during testing provides the highest fidelity testing available which is representative of the end-user experience, which may improve quality of the application as released to the end user.

Illustrative Environment

FIG. 1 depicts an environment 100 for testing markup language applications executing on a remote or external computing device. In some implementations, the techniques

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described herein may be used to test markup language applications executing on a simulated computed device.

A development device **102** is depicted. The development device **102** is configured to execute, at least in part, one or more development tool modules **104**. The development tool module **104** provides applications for testing, debugging, runtime editing of the application being tested, and so forth. The development tool module **104** may include the Safari® Inspector as developed by Apple Corp., the GNU debugger (“gdb”) as maintained by the GDB Steering Committee, Google Developer Tools (DevTools) as promulgated by Google, Inc., and so forth. The development tool modules **104** are discussed in more detail elsewhere in this application.

The development device **102** may be used to test one or more local applications under test **106**. This local application under test **106** includes a markup language application **108**. The development tool module **104** may be configured to provide testing of the local application under test **106**. This testing may include the development tool module **104** providing one or more commands **110** to a local layout engine module (not depicted here). The local layout engine module is configured to execute or interpret the markup language application **108**, and return output data **112**. The output data **112** may include crash dumps, register values, memory information, timing data, hardware resource usage data, and so forth.

In one implementation the layout engine module may comprise WebKit® as promulgated by Apple Corp. and others. In this implementation, the commands **110** may be debugging commands compatible with the WebKit® layout engine and internal components such as the WebCore, JSCore, and so forth. For example, commands may be deemed “compatible” when such commands are operable to be processed by a module to change state, change operation, and so forth.

In this illustration, the development tool module **104** is providing commands **110(1)** to the markup language application **108(1)** which is local to the development device **102**. The development tool module **104** may receive the output data **112(1)** resulting from the execution of the markup language application **108(1)** by the local layout engine module.

The development tool module **104** may provide session data **114**. The session data **114** may be stored in a JavaScript Object Notation (JSON) format. The session data **114** may include data based at least in part on the commands **110**, the output data **112**, and so forth. The session data **114** may be saved for later analysis, sent to another device, and so forth. In some implementations, the development tool module **104** may be configured to replay previously stored session data **114**. The development device **102** is described in more detail elsewhere in this application, such as in regard to FIG. 3.

As described above, testing using a particular computing device platform provides valuable information which is useful to the software developer and others. One or more computing devices **116** may be coupled to the development device **102**. This coupling enables the development tool module **104** of the development device **102** to test a markup language application **108(2)** on the computing device **116**. Because of the coupling and testing facilities made available through the development tool module **104**, debug code or other testing instructions may be omitted from a remote application under test **124**.

The computing device **116** may include a native application **118**, the markup language application **108**, a hybrid application **120**, a browser-based application **122**, or a combination thereof.

The native application **118** is written and compiled for execution on the particular computing device **116** platform. For example, native applications may be written in a pro-

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gramming language such as C++ or Objective C and compiled into native code such as a binary executable for use on the device having a particular processor and operating system.

In comparison, markup language applications **108** include one or more instructions in a markup language which is rendered and a scripting language which is interpreted by a scripting language engine during execution. For example, a hypertext markup language (“HTML”) version 5 (or higher) markup language application may include HTML and cascading style sheets (“CSS”) as the markup language and JavaScript as the scripting language. In some implementations the markup language application **108** may have multiple instances of the UIWebView class references.

The hybrid applications **120** include native code as well as markup language application portions. For example, portions of native code may be used to interact with platform-specific hardware such as a graphics processing unit while portions of markup language provide business logic and user interface elements.

The browser-based applications **122** are processed within a web browser application and may be limited in their execution by the constraints of the web browser. The browser-based applications **122** may include rendering of a particular web page or group of web pages, such as expressed at least in part by a markup language, such as HTML5. The browser-based application **122** is executed within a particular sandbox and executes within the web browser. The browser-based applications may have only a single UIWebView instance. Browser-based applications **122** may be further constrained in that they may share caches and other resources with the web browser and also occupy the same sandbox as the web browser. Sandboxing and distinctions between the different applications are discussed elsewhere in this application, such as in regard to FIG. 2.

The computing device **116** may include one or more of the remote applications under test **124**. These applications are “remote” or “external” in that they are executing on a different device from the development device **102** and the development tool module **104**. The remote applications under test **124** may include the markup language application **108(2)**, the hybrid application **120**, or both.

The remote applications under test **124** may use a layout engine module **126** during execution. In one implementation the layout engine module **126** may comprise WebKit® as promulgated by Apple Corp. and others. In this implementation, the commands **110** may comprise WebKit® commands.

The layout engine module **126** may include one or more libraries **128**, scripting language engines **130**, embedded test tools **132**, and so forth. The libraries **128** may comprise previously stored program instructions which may be called by applications during execution. These libraries **128** may include those involved in layout, rendering, document object model (“DOM”) creation, graphics libraries, and so forth. In one implementation the graphics libraries may include WebGL™ as promulgated by the Khronos Group of Beaverton, Oreg.

The scripting language engines **130** are configured to interpret and execute the scripting language portion of the markup language application **108** or the hybrid application **120**. In the WebKit® implementation the scripting language engine **130** may comprise the JavaScript Core. Other scripting language engines **130** may also be present. For example, the Nitro JS engine provided by Apple Corp., the Carakan JavaScript engine provided by Opera Software of Oslo, Norway, and so forth may be available on the computing device **116** for use.

These may be regularly available on the computing device **116**, or may be specifically loaded onto the computing device **116** for testing purposes.

The layout engine module **126** may include one or more of the embedded test tools **132**. The embedded test tools **132** are functionalities in the layout engine module **126** which may be used for testing. The embedded test tools **132** may include facilities for runtime editing, providing memory allocation information, platform resource usage information, and so forth. The embedded test tools **132** are configured to interact with the scripting language engine **130** or other portions of the layout engine module **126**. For example, in one implementation the embedded test tools **132** may comprise the Mobile Safari® web inspector, such as implemented by the “com.apple.webinspectord” service executing on a computing device **116** which uses the Apple iOS® operating system. The embedded test tools **132** may generate the output data **112**. The embedded test tools **132** may be used in conjunction with the development tool module(s) **104** executing on the development device **102** to provide various testing capabilities to the software developer.

Communication between the development tool module **104** on the development device **102** and the layout engine module **126** may be provided in some implementations by a communication module **134** and an unpack module **136**. The communication module **134** is configured to send and receive information to a device external to the computing device **116**, such as the development device **102**. The communication module **134** may use various physical transports to exchange information including universal serial bus (“USB”), Institute of Electrical and Electronics Engineers (“IEEE”) 1394 “Firewire”, wired Ethernet, wireless such as Wi-Fi or Bluetooth, and so forth. Transmission control protocol (“TCP”), user datagram protocol (“UDP”) or other transport layer protocols may be used in conjunction with the physical transports to exchange information between the development device **102** and the computing device **116**. In one implementation the physical transport may comprise USB and data may be sent using hypertext transport protocol (“HTTP”) over TCP (“HTTP/TCP”), WebSockets, and so forth.

In one implementation, the communication module **134** may comprise a lightweight HTTP server. This server is configured to send and receive data, and is considered lightweight in that it executes with relatively small resource overhead and has a more limited feature set than that provided by a typical web server application, such as Apache HTTP server. For example, the communication module **134** may omit functions such as support for HTTP Secure (“HTTPS”).

In another implementation, the communication module **134** may be configured to provide TCP over USB. For example, the communication module **134** may implement the “usbmuxd” daemon.

The communication module **134** may receive packed commands **138** from the development tool **104** of the development device **102**. The commands **110** may be packetized or otherwise manipulated for transport between the development tool module **104** on the development device **102** and the computing device **116**, forming the packed commands **138**. The communication module **134** passes the received packed commands **138** to the unpack module **136**.

The unpack module **136** is configured to process the packed commands **138** and provide unpacked commands **110** (2) to the layout engine module **126**. The processing may include removing transport-associated information such as headers, routing information, and so forth. For example, the unpack module **136** may remove TCP headers and reassemble payloads across multiple packets to form the com-

mands **110**(2). In some implementations the unpacked commands **110**(2) may be in extensible markup language procedure call (“XPC”) format.

The unpack module **136** provides the unpacked commands **110**(2) to the layout engine module **126** for processing. The unpacked commands **110**(2) are compatible with the embedded test tools **132** and other aspects of the layout engine module **126** and an associated framework. Just as the development tool module **104** may send commands **110**(1) associated with the local application under test **106**, the development tool module **104** may send commands **110**(2) associated with the remote application under test **124**. The layout engine module **126** may be configured to operate such that commands **110** are provided and responses such as the output data **112** are generated.

The development tool modules **104** may include one or more developer modules **140**, a proxy module **142**, and a driver module **144**. The developer modules **140** may include code editor modules **146**, debug modules **148**, automated test modules **150**, or other modules **152**. The developer modules **140** may be configured to generate one or more commands **110**. For example, generation may include creation of a command **110**, replay of a previously stored command, and so forth. The code editor modules **146** may include tools for the developer to change the markup language expressions in the markup language application **108**, perform runtime editing, and so forth. The debug modules **148** may provide for step by step execution, crash analysis, and so forth. The automated test modules **150** may allow for creation, editing, and playback of test script data which may be used to automate at least a portion of a testing regimen. Other modules **152** may provide other testing functionality. For example, a fuzzing module may be configured to generate inputs which may be applied to the markup language application **108** or another application under test. In one implementation the developer modules **140** may include one or more of the applications, libraries, executables, application programming interfaces (APIs), and so forth present in the Google DevTools as promulgated by Google, Inc. In some implementations the developer modules **140** may generate commands **110** which are compliant with at least a portion of the remote debugging protocol as promulgated by Google, Inc.

The proxy module **142** is configured to provide a communication proxy between the development tool modules **104** or the driver module **144** and modules executing on the computing device **116**. For example, the proxy module **142** may provide for communication between a Chrome™ DevTool on the development device **102** and the web inspector daemon “com.apple.webinspectord” executing on the computing device **116**. The proxy module **142** may encapsulate, pack, or otherwise process the commands **110** or other data for transfer. For example, in one implementation the proxy module **142** may generate packed commands **138** from the commands **110** provided by one or more of the developer modules **140**.

The proxy module **142** may be configured to provide communications interfaces or ports. For example, the proxy module may provide a first set of one or more WebSockets which are available to communicate with the developer modules **140** and the driver module **144**, and a second set of one or more WebSockets which are available to communicate with services or modules executing on the computing device **116**. In some implementations, the WebSocket protocol may be compliant with the Internet Engineering Task Force RFC 6455.

The proxy module **142** may maintain multiple sessions or WebSocket ports for a single computing device **116**. For example, in one implementation, a separate WebSocket port

may be provided for each tab within a browser application executing on the computing device **116**.

The driver module **144** is configured to receive commands **110** in a first form and convert those commands **110** to a second form. For example, the driver module **144** may receive commands **110** in a first form which is compatible with the remote debugging protocol and provide commands **110** which are compatible with the WebKit® of the layout engine module **126**. Continuing the example, the command **110** may designate a URL to open and render within a web browser.

In some implementations the driver module **144** may be implemented using the Ruby programming language as developed by Yukihiro Matsumoto and described at www.ruby-lang.org. The driver module **144** may be used to provide a command line interface (CLI). The command line interface may accept commands manually, such as when the developer types them into the CLI, or may accept commands which have been previously written, such as from test script data.

Using the techniques described, a single development device **102** may perform testing using one or more computing devices **116**. For example, the single development device **102** may be connected to, and performing testing using, four computing devices **116(1)**, **116(2)**, **116(3)**, and **116(4)**. The testing may be automated, allowing for long duration and more comprehensive tests across multiple devices, compared to testing on a single computing device **116** at a time.

The modules in this disclosure may be described as separate modules for ease of illustration, and not by way of limitation. For example, the communication module **134** and the unpack module **136** are described in this disclosure as separate modules. In some implementations at least a portion of the functionality of these modules may be combined into a single module, or incorporated into another module. The computing device **116** is described in more detail elsewhere in this application, such as in regard to FIG. 4.

FIG. 2 illustrates different types **200** of applications available for execution on the computing device **116**. As described above, these types include the native application **118**, the markup language application **108**, the hybrid application **120**, and the browser-based application **122**.

Some operating systems executing on the computing devices **116** may provide for sandboxes **202** or sandboxing. The sandbox **202** comprises an environment with access controls applied to executing processes. These access controls may be provided to limit or control interactions between the executing applications and with other devices or applications. Sandboxing may be used to mitigate the effects of malicious or improperly-coded applications. In some implementations the sandboxes **202** may be implemented as separate virtual machines within which the application may execute. Some operating systems, such as the iOS® operating system by Apple Corp. provide for sandboxing applications.

In this illustration four sandboxes **202(1)-(4)** are depicted, with a different application in each. However, it is understood that in some implementations, sandboxing may be omitted and the various applications may execute in a common environment.

The sandbox **202(1)** contains the native application **118**. As described above, the native application **118** is written and compiled for execution on the particular computing device **116** platform. The native application **118** comprises native code **204** and may also include one or more data files **206**. The native code **204** comprises a binary executable for use on a particular platform. For example, the native application **118** may be written in a programming language such as Objective C and compiled into native code **204(1)**. The data files **206(1)**

may include application cache, proxy server caches, user preferences, user data, and so forth. For example, in one implementation the data files **206** may include a cache used by a web browser application.

The sandbox **202(2)** contains the markup language application **108(2)**. The markup language application **108(2)** includes one or more instructions expressed in a markup language **208**. The markup language **208** may use one or more tags to specify particular rendering of content. For example, the markup language **208** may comprise instructions compliant with hypertext markup language (“HTML”) version 5 (or higher). The markup language **208** may also include cascading style sheets (“CSS”). While the examples in this disclosure use HTML5 or later, the systems and methods described may also be applied to other markup languages.

The markup language application **108(2)** may also include instructions expressed in a scripting language **210**. The scripting language **210** is configured for processing by an interpreter during execution. For example, the scripting language **210** may comprise JavaScript and the interpreter may comprise the JavaScript Core in WebKit®. While the examples in this disclosure use JavaScript, the systems and methods described may also be applied to other scripting languages.

In some implementations the markup language application **108** may have multiple instances of the UIWebView **212** class references. These UIWebView **212** instances enable presentation of content expressed using a markup language **208** such as HTML5 with CSS and a scripting language **210** such as JavaScript. For example, as depicted here, the markup language application **108(2)** may have UIWebView instances **212(1)-(3)**.

The markup language application **108** may also have one or more data files **206**. As described above, the data files **206(2)** may include property list (“PLIST”) files, caches, user preferences, user data, icons, cookies, databases, temporary files, temporary directories, and so forth. In some implementations a portion or all of the data files **206** may be stored on a remote device, such as a backend server accessible via the Internet. Software developers may thus minimize or eliminate the data which is stored locally on the computing device **116**. This may be done to reduce local storage requirements, improve security of the data, and so forth. For example, upon loss or compromise of the computing device **116**, the backend server may terminate access, safeguarding the data. Use of the backend server may also minimize or eliminate the complexity associated with encrypting contents in the data files **206** to further safeguard data. The implementation of the markup language application **108** as a front end and the use of the backend server allows for easier purging of data associated with the application when the application is exited or terminated.

The development tool module **104** may be configured to access information about the data files **206** and present that information to the developer for testing, debugging, inspection, and so forth of the local store associated with the remote application under test **124**.

For example, consider an example markup language application **108(2)** executing in the sandbox **202(2)** of the computing device **116** which is executing the iOS® operating system. In this example, the data files **206**, such as **206(2)**, which are associated with remote applications under test **124** may be stored on the computing device **116** at a directory location `/var/mobile/Applications/[device specific]` where `[device specific]` indicates a value which may vary from one computing device **116** to another. The files may be analyzed, debugged, or tested, using various tools of the development tool module **104** as appropriate to the file types. For example,

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where the *.db files indicated above such as EAsyncstore.db use SQLite as developed by D. Richard Hipp and others, the sqlite3 utility be used to execute commands against the database.

As described above, the data files **206** may also include session cookies. A command **110** may be used to retrieve these session cookies.

The development tool module **104** may also include the plutil as provided with the Mac OS from Apple Corp. to interact with session PLIST files, user data PLIST files, and so forth.

By using the development tool module **104**, the developer may assess the data files **206** which are locally stored on the computing device **116** by the remote application under test **124**. For example, the above information about the data files **206** may be presented within the Safari® Inspector.

In some implementations the data files **206** may be cleared prior to, during, or after testing. For example, a command **110** may be issued by a developer module **140**. The command **110** may be configured to clear a browser cache prior to testing page load times. In some implementations other caches such as a cache used by a proxy server may be cleared.

To clear the cache, or provide other actions on data in the file system of the computing device **116**, the file system of the computing device **116** may be mounted by the development device **102**. Once mounted, files, such as cache files, may be deleted.

In the implementation described below, a Filesystem in Userspace (FUSE) kernel module may be loaded on a computing device **102** which is executing the MacOS from Apple Corp. In one implementation MacFUSE may be used. MacFUSE may be obtained from <http://code.google.com/p/mac-fuse/> or other locations. The following example illustrates the use of MacFUSE; however other FUSE implementations may also be used, such as OSXFuse.

A fuse kernel module is loaded into the kernel, such as by the command:

```
insmod fuse.ko
```

The userid of mountAppDirectory may be added to the fuse group using:

```
adduser <uid> fuse
```

The MacFUSE application may be installed, and the command “run mountAppDirectory” may be executed. The MACFuse application attempts to connect with the Apple File Connection (AFC) or AFC2 using lockdownd. The iOS® operating system module of the computing device **116** provides the AFC/AFC2 service.

The document sharing service com.apple.mobile.house_arrest which is available on iOS® may then be started. The house_arrest makes an app container of the markup language application **108** which is undergoing testing available for sharing. Using the AFC/AFC2 connection, the directory is accessible using MACFuse. Once accessible file operations such as cache files associated with the browser application module **414** may be deleted.

The sandbox **202(3)** depicts the hybrid application **120**. As described above, the hybrid application **120** includes native code **204** as well as markup language **208**, scripting language **210**, or both. For example, portions of native code **204** may be used to interact with platform-specific hardware such as a graphics processing unit (GPU) or satellite navigation receiver, while portions of markup language provide business logic and user interface elements, such as controlling display of mapping information. Similar to the markup language application **108**, multiple instances of the UIWebView **212(4)**

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and **212(5)** class references may be present. The hybrid application **120** may also have one or more associated data files **206(3)**.

The sandbox **202(4)** depicts the browser-based applications **122**. Browser-based applications **122** are processed within a web browser application and are limited in their execution by this constraint. The browser-based application **122** may include a web page or collection of web pages. In one implementation the web browser application may be the Safari® browser (also known as “Mobile Safari”) by Apple Corp. and executing in the iOS® operating system, while in another implementation the web browser application may be the Chrome™ browser by Google, Inc. and executing in the iOS® operating system, the Android operating system, and so forth. The web browser application may access one or more of the markup language **208** or scripting language **210** for rendering and execution. The browser-based application **122** may have only a single UIWebView **212** instance.

The web browser application’s native code **204(3)**, the rendered markup language **208**, the executed scripting language **210**, the corresponding single UIWebView **212(6)** instance, and the data files **206(4)** share the same sandbox **202(4)**. As a result, there is a potential for unwanted or undesired interactions. For example, the scripting language **210** may improperly invoke a function in the native code **204(3)** and generate an error or malicious condition.

Among the types of applications, the markup language application **108** provides a useful blend of benefits. Cross-platform development and maintenance is less than that of native applications **118**. Hybrid applications **120** leverage platform-specific native code **204** with the cross-platform capabilities of the markup language **208** and the scripting language **210**. The markup language application **108** readily supports multiple UIWebView instances **212** allowing for rich application experiences compared to browser-based applications **122**. Compared to the browser-based applications **122**, the markup language application **108** and the hybrid application **120** may experience improved security by operating in a separate sandbox **202**, omitting the web browser application, and so forth.

FIG. 3 depicts a block diagram **300** of the development device **102** configured to perform operations for testing markup language applications **108**. The development device **102** may include one or more hardware processors **302** (processors) configured to execute one or more stored instructions.

The development device **102** may include one or more input/output (I/O) interface(s) **304** to allow the development device **102** to communicate with other devices. For example, the I/O interface(s) **304** may be configured to provide a universal serial bus (USB) connection compliant with the standards promulgated by the USB Implementers Forum, Inc. of Beaverton, Oreg. to couple to the computing device **116**.

The I/O interface(s) **304** may couple to one or more I/O devices **306**. The I/O device(s) **306** may include user input devices such as one or more of a keyboard, a mouse, a pen, a game controller, a voice input device, a touch input device, a gestural input device, and so forth. The I/O device(s) **306** may include output devices such as one or more of a display, a printer, audio speakers, haptic output devices, and so forth. In some embodiments, the I/O device(s) **306** may be physically incorporated with the development device **102** or be externally placed.

The development device **102** may also include one or more network interfaces **308** to enable communications between the development device **102** and other networked devices. Such network interface(s) **308** may include one or more net-

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work interface controllers (NICs) or other types of transceiver devices configured to send and receive communications over the network(s). For example, the network interface(s) **308** may be configured to provide a wired network connection, wireless Wi-Fi connection compliant with one or more IEEE 802.11 standards such as 802.11g or 802.11n, and so forth. The development device **102** may also include one or more busses or other internal communications hardware or software that allow for the transfer of data between the various modules and components of the development device **102**.

The development device **102** includes one or more memories **310**. The memory **310** comprises one or more computer-readable storage media ("CRSM"). The CRSM may be any one or more of an electronic storage medium, a magnetic storage medium, an optical storage medium, a quantum storage medium, a mechanical computer storage medium, and so forth. The memory **310** provides storage of computer readable instructions, data structures, program modules, and other data for the operation of the development device **102**.

The memory **310** may include at least one operating system (OS) module **312**. The OS module **312** is configured to manage hardware resources such as the I/O interface(s) **304** and network interface(s) **308**, and to provide various services to applications or modules executing on the processor(s) **302**. In some implementations, the OS module **312** may comprise one or more operating systems configured for execution on the development device **102**. For example, the OS module **312** may implement one or more of Mac OS® from Apple Corp. of Cupertino, Calif.; Windows® from Microsoft Corp. of Redmond, Wash.; Linux and its derivatives from various sources; FreeBSD; UNIX; or other operating systems.

The memory **310** may include a user interface module **314**, the development tool module **104**, a local application under test **106**, one or more of the developer modules **140**, or other module(s) **316**. For example, the memory **310** may store at least a portion of the development tool module **104** and developer modules **140** such as the Safari® Inspector from Apple Corp., the Chrome™ DevTools, and so forth.

The memory **310** also includes a datastore **318** to store information for operations of the development device **102**. The datastore **318** may comprise a database, array, structured list, tree, executable code, markup language, or other data structure. In some implementations, the datastore **318** may store remote application under test connection data **320**. For example, the connection data such as USB port, device identifier, address, and so forth may be stored. Test script data **322** may be stored which defines particular tests or functions to be executed by the development tool module **104** against an application under test. The test script data **322** may comprise a series of instructions or commands configured to initiate or otherwise perform the tests or functions to exercise the application under test. In one example, the test script data **322** may comprise one or more commands configured to clear a browser cache, initiate a debugging session, enable a web inspector, specify a network address, open a web page at the network address, and so forth.

In some implementations the test script data **322** may be provided as described in U.S. patent application Ser. No. 13/868,560, filed on Apr. 23, 2013, titled "Test Script Generation" to Manish Lachwani, et al. which has been incorporated by reference into this disclosure.

The session data **114** may be stored in the datastore **318**. As described elsewhere in this disclosure, in some implementations the session data **114** may be stored in a JSON format.

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Example JSON session data:

```
[{
  "devtoolsFrontendUrl":
5 "src/devtools/devtools.html?host=localhost:8999&page=1",
  "faviconUrl": " ",
  "thumbnailUrl":
  "/thumb/http://news.example.com/?ar=1386497377#pcid=FRONTPAGE",
  "title": "Google News",
  "url":
10 "http://news.example.com/?ar=1386497377#pcid=FRONTPAGE",
  "websocketDebuggerUrl":
  "ws://localhost:8999/devtools/page/1"
}, {
  "devtoolsFrontendUrl":
15 "src/devtools/devtools.html?host=localhost:8999&page=2",
  "faviconUrl": " ",
  "thumbnailUrl": "/thumb/http://www.example2.com/south-
africa-v-india-2013-14/engine/match/648653.html",
  "title": "2nd ODI: South Africa v India at San Jose, Dec
12, 2013 | Cricket Scorecard | ABCD Cricinfo",
  "url": "http://www.example2.com/south-africa-v-india-
20 2013-14/engine/match/648653.html",
  "websocketDebuggerUrl":
  "ws://localhost:8999/devtools/page/2"
}]
```

Other data **320** may also be stored, such as software developer preferences, configuration settings for the development tool module **104**, and so forth.

FIG. 4 depicts a block diagram **400** of the computing device **116** configured to perform operations for testing markup language applications **108**. The computing device **116** may include one or more processors **402** configured to execute one or more stored instructions. The processors **402** may comprise one or more cores.

The computing device **116** may include one or more input/output (I/O) interface(s) **404** to allow the computing device **116** to communicate with other devices. For example, the I/O interface(s) **404** may be configured to provide a universal serial bus (USB) connection to couple to the development device **102**.

The I/O interface(s) **404** may couple to one or more I/O devices **406**. The I/O device(s) **406** may include user input devices such as one or more of a keyboard, a mouse, a pen, a game controller, a voice input device, a touch input device, a gestural input device, or other devices. The I/O device(s) **406** may include output devices such as one or more of a display, a printer, audio speakers, haptic output devices, and so forth. In some embodiments, the I/O device(s) **406** may be physically incorporated with the computing device **116** or be externally placed.

The computing device **116** may also include one or more network interfaces **408** to enable communications between the computing device **116** and other networked devices such as those depicted in FIG. 1. Such network interface(s) **408** may include one or more network interface controllers (NICs) or other types of transceiver devices configured to send and receive communications over the network(s). For example, the network interface(s) **408** may be configured to provide a Wi-Fi connection compliant with one or more IEEE 802.11 standards such as 802.11g or 802.11n. The computing device **116** may also include one or more busses or other internal communications hardware or software that allow for the transfer of data between the various modules and components of the computing device **116**.

The computing device **116** includes one or more memories **410**. The memory **410** comprises one or more CRSM as described above. The memory **410** provides storage of com-

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puter readable instructions, data structures, program modules, and other data for the operation of the computing device **116**.

The memory **410** may include at least one operating system (OS) module **412**. The OS module **412** is configured to manage hardware resources such as the I/O interface(s) **404** and network interface(s) **408**, and to provide various services to applications or modules executing on the processor(s) **402**. In some implementations, the OS module **412** may comprise one or more mobile operating systems configured for execution on mobile computing devices. For example, the OS module **412** may implement one or more of iOS® from Apple Corp. of Cupertino, Calif.; Windows Mobile® from Microsoft Corp. of Redmond, Wash.; Android® from Google, Inc. of Mountain View, Calif. and its derivatives from various sources; Palm OS® from Palm Computing, Inc. of Sunnyvale, Calif. and its derivatives from various sources; BlackBerry OS® from Research In Motion Ltd. of Waterloo, Ontario, Canada; or other operating systems such as VxWorks from Wind River Systems of Alameda, Calif. In cases where the OS module **412** implements a version of iOS®, any version of iOS® may be supported including iOS® 1.x, 2.x, 3.x, 4.x, 4.x, 6.x, 7.x, or higher versions, including any version of iOS® for the iPhone®, iPad®, iPod Touch®, or any other compatible, derivative, or related device. In cases where the OS module **412** implements a version of Android®, any version of Android® may be supported including but not limited to versions 2.3.x “Gingerbread,” 4.0.x “Ice Cream Sandwich,” 4.1.x “Jelly Bean,” and so forth. As described above with regard to FIG. 2, in some implementations the OS module **412** may be configured to sandbox applications **202**.

The memory **410** may include a browser application module **414**. This browser application module **414** may be implemented as a native application **118**, compiled for execution on the particular platform of the computing device **116**. For example, where the platform comprises an Apple Corp. device running the iOS® operating system, the browser application module **414** may comprise the Safari® mobile browser.

The memory **410** may also include the layout engine module **126** as described above. In some implementations the layout engine module **126** may comprise the WebKit® framework and associated libraries **128**, scripting language engine **130**, and embedded test tools **132**. The browser application module **414** or other applications on the computing device **116** may utilize at least a portion of the layout engine module **126** during operation. For example, the Safari® mobile browser may use the JavaScript core in WebKit® for execution of the scripting language **210** which comprises JavaScript.

The layout engine module **126** may be initialized prior to testing. The initialization may be configured to activate the embedded test tools **132**. For example, where the layout engine module **126** comprises WebKit®, the WebKit® listener may be placed into an inspection mode configured to receive commands from the Safari® Inspector. In another example, the web inspector process com.apple.webinspector may be loaded. In this example, the lockdownd process present in iOS® may be used to start com.apple.webinspector.

In some implementations where information about how to initialize or otherwise activate the embedded test tools **132** is not readily available, the layout engine module **126** or other applications may be analyzed as described in U.S. patent application Ser. No. 13/631,919, filed on Sep. 29, 2012, titled “Application Validation Through Object Level Hierarchy

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Analysis,” and in U.S. patent application Ser. No. 13/655,667, filed on Oct. 19, 2012, titled “Application Auditing Through Object Level Code Inspection,” both of which are incorporated by reference into this disclosure.

The testing described herein may further be facilitated using the systems and methods described in U.S. patent application Ser. No. 13/619,867, filed on Sep. 14, 2012, titled “Remote Control of a Mobile Device” which is incorporated by reference into this disclosure.

The communication module **134** and the unpack module **136** are also stored in the memory **410**. As described above, the communication module **134** is configured to send and receive information to a device external to the computing device **116**, such as the development device **102**. In one implementation, the communication module **134** may comprise a lightweight HTTP server. In another implementation, the communication module **134** may comprise the Apple Corp. usbmuxd process which provides data transport over the USB connection.

As also described above, the unpack module **136** is configured to process the packed commands **138** and provide unpacked commands **110(2)** to the layout engine module **126**. The unpacked commands **110(2)** are compatible with the embedded test tools **132** and other aspects of the layout engine module **126** and an associated framework. In some implementations, the commands **110** may be provided by the developer modules **140** directly, or may be provided by the driver module **144**.

The memory **410** may include native applications **118**, markup language applications **108**, hybrid applications **120**, browser-based applications **122**, and so forth. As described above, the remote applications under test **124** may include one or more of the markup language application **108**, the portion of the hybrid application **120** which is non-native code, or the portion of the browser-based application **122** which uses a markup language.

Other modules **416** may also be stored in the memory **410**, such as digital rights management modules, speech recognition modules, and so forth.

The memory **410** also includes a datastore **418** to store information for operations of the computing device **116**. The datastore **418** may comprise a database, array, structured list, tree, or other data structure. The datastore **418** may store the packed command data **138**, unpacked command data **110(2)**, the output data **112**, or both. Other data may also be stored, such as user preferences, configuration settings, and so forth.

The techniques described in this disclosure may use one or more services, applications, or processes which are provided by the OS module **412** in a secured configuration, such as a non-jailbroken device as shipped from a manufacturer. For example, the development tool module **104** may be used to gather session data **114** associated with the remote application under test **124**, such as the markup language application **108(2)**. This may occur without the use of root or super user privileges.

However, in other cases, one or more modifications may be made to the computing device **116**. For example, the OS module **412** may be “rooted” or “jailbroken” prior to installation of the communication module **134**, the unpack module **136**, and so forth. “Rooting” or “jailbreaking” may include bypassing one or more security constraints imposed by the OS module **412**, and may provide unrestricted (or minimally restricted) access to the file system, portions of the OS module **412**, processes executing on the computing device **116**, and so forth. For example, root or super user privileges may

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be available on a jailbroken device, as compared to a non-jailbroken in which root or super user privileges are unavailable or strictly curtailed.

FIG. 5 depicts a user interface **500** of testing options which may be selected for testing. Several options may be selected which may affect the execution of the remote application under test **124**. These options may include one or more of specifying a network address of a web page to test **502**, enabling video capture **504**, using an automated test script **506**, testing on all available connected computing devices **508**, sending session data after completion **510**, collecting timeline data **512**, collecting network event data **514**, retrieving device console logs **516**, retrieving app crash reports **518**, generating page load characteristics **520**, and so forth.

The option to specify network address of a web page to test **502** may be used to test performance of a particular web page. For example, the user may specify a URL with a web page to load and render in the browser application **414**.

The option to enable video capture **504** may be used to capture video output as presented on the display of the computing device **116** during a run of the test. For example, the developer may select this option such that when a failure in execution of the markup language application **108** is determined, the failure may be observed.

The option to use an automated test script **506** may allow for automated testing. Automated testing allows one or more tests to be run one or more times without human intervention during the testing. The automated testing may use the test script data **322** described above. The automated tests may be manually created or automatically generated.

The option to test on all available connected computing devices **508** may allow for the use of a plurality of computing devices **116** which are connected to the development device **102**. For example, the testing may be performed on twenty computing devices **116** attached to the development device **102**.

The option to send session data after completion **510** may be used to send the session data **114** to another developer module **140**, development device **102**, external server, and so forth. For example, the session data **114** may be sent to a build server following completion of testing.

The option to collect timeline data **512** may be used to collect information about what actions by the markup language application **108** occur at what times, in what sequence, and for how long. For example, the Chrome™ DevTools provide a JavaScript Console which includes timeline functionality.

The option to collect network event data **514** may be used to acquire data about information which is sent to and from one or more of the network interfaces **408** by the markup language application **108**. For example, the Chrome™ DevTools provide network event capture and analysis capabilities.

The option to retrieve device console logs **516** may be used to access console logs generated on the computing device **116**. For example, the console logs may provide information about kernel failures, application crashes, and so forth.

The option to retrieve app crash reports **518** may be used to access crash reports from the computing device **116**. The crash reports may be generated by the OS module **412**, the layout engine module **126**, and so forth.

The option to generate page load characteristics **520** may be used to acquire information, or calculate from previously acquired session data **114**, information about load times of the markup language application **108**. For example, this may include determining time to load a document object model (DOM), time to load the entire page, and so forth. In some

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implementation, selection of this option may result in commands **110** being sent to the computing device **116** to clear a browser cache or other previously stored files associated with the markup language application **108** being tested.

In some implementations, selection of one option may result in selection or deselection of another option. For example, selection of the option to generate page load characteristics **520** may result in deselection of the option to collect timeline data **512** as this may result in significant overhead on the computing device **116**, distorting the resulting page load times.

Other options and tests may be available as well. These may include, but are not limited to, retrieving DOM debugger and script parsing output, retrieving information about processor bound threads, heap size utilization, rendering time, paint time, measuring hardware statistics such as memory, processor, disk, network, and so forth.

By allowing the developer to collect and access this information, particularly in an automated fashion on real browser applications executing on actual computing devices **116**, the development process is improved. The impact of changes in the code of the markup language application **108** may be determined and debugged, which may result in improved markup language applications **108**.

Other options may be provided as well. For example, the developer may specify use of particular audio libraries for use in audio processing.

FIG. 6 depicts a user interface **600** of output data **112**. The output data **112** may be received using the communication module **134** from the remote application under test **124** executing on the computing device **116**. In other implementations, the output data **112** may be stored locally to the computing device **116** and retrieved. In some implementations the development tool module **104** may provide this user interface **600**. The session data **114** may also be used in some implementations to provide the information presented in this user interface **600**.

The output data **112** is depicted in a graphical user interface, however in other implementations the information may be presented as a character user interface, or may be stored for processing by another application. For example, the output data **112** may be stored for processing by an analytical application such as Splunk by Splunk Inc. of San Francisco, Calif., Nagios as promulgated by Nagios Enterprises LLC of Saint Paul, Minn.

The user interface **600** may include one or more indications **602** of options which have been selected. For example, these may include the options discussed above with respect to FIG. 5.

A runtime editing code view **604** is presented. In this view, the software developer may see a portion of the code such as the markup language **208**, the scripting language **210**, or both, at a particular point in execution. For example, the runtime editing code view **604** may present a portion of the code where an error has occurred. The runtime editing code view **604** may also allow the software developer to make changes to the code for subsequent testing.

Memory allocation and leak detection data **606** may be depicted. This information may include information such as memory allocated to particular processes. For example, the software developer may use this information to determine that the markup language application **108** has a particular process which has been allocated memory for use but is not released after use or is inaccessible.

Timeline data **608** may be presented. The timeline data **608** may present information about which elements have been accessed, the duration of that access, and so forth. Network

bandwidth data **610** may also be presented. The network bandwidth data **610** provides information about a quantity of data transferred with respect to a particular element and the duration of that transfer.

A control to play video capture of a particular test **612** may be provided. For example, the user interface **600** may provide a control to playback the video capture of the test session.

CPU usage data **614** or other information about hardware resource usage on the computing device **116** may also be presented. In this illustration, various threads of the remote application under test **124** and their associated usage of processor **402** resources may be presented to the software developer.

Page load information **616** may be provided in the user interface **600**. For example, in this illustration details about a particular SEND request and a maximum amount of memory used during page load is presented.

In some implementations, the user interface **600** may also provide information indicating the operating system executing on the computing device **116**. For example, the tests were run on a computing device **116** executing iOS 7.0.4.

The test results and functions depicted are provided for illustration, and not by way of limitation. In some implementations additional tests may be added, some tests may be omitted, and so forth.

Illustrative Processes

FIG. 7 depicts a flow diagram **700** of a process of the proxy module **142** operating on the development device **102** during debugging of the remote application under test **124**. The remote application under test **124** may comprise a markup language application **108**. As described above the markup language may comprise HTML version 5 or higher.

Block **702** provides a first set of one or more ports. The first set of one or more ports are accessible to the developer modules **140**, the driver module **144**, or both. The proxy module **142** may be configured to receive the one or more commands **110** at the first set of one or more ports.

Block **704** establishes communication with one or more external computing devices **116** coupled to the development device **102**. In one implementation, this may include initiating a connection via a USB using the Mobile Device framework as promulgated by Apple Corp. with the external computing device **116** executing a version of the iOS® operating system version 7.0 or higher as promulgated by Apple Corp.

As described, the external computing device **116** may be configured to execute the layout engine module **126** within an operating system having a secured configuration. For example, where the computing device **116** is executing the iOS® operating system, the OS module **412** may not be “jailbroken”.

Block **706** provides a second set of one or more ports. The second set of one or more ports are accessible to one or more of the modules which may execute on the computing device **116**. For example, the second set of one or more ports may be accessible to the layout engine module **126** which is executable on the external computing device **116**. As described in this disclosure, the layout engine module **126** may comprise one or more portions of WebKit®, the com.apple.webinspector daemon, or a combination thereof. Communication may be established with the external computing device **116** using the second set of one or more ports.

The first set of ports, the second set of ports, or both, may be compliant with the WebSocket protocol as promulgated by the Internet Engineering Task Force Request For Comments (RFC) 6455. In one implementation, such as where the driver module **144** is implemented using the Ruby programming

language, the faye WebSocket implementation may be used. Faye is promulgated by James Coglan at faye.jcoglan.com.

Block **708** transfers data such as the commands **110**, the output data **112**, and so forth between the first set of one or more ports and the second set of one or more ports. For example, the command **110** received by the first set of ports from the debugger module **148** may be passed via a WebSocket connection of the first set of one or more ports, and transferred to the second set of one or more ports for delivery to the layout engine module **126**. In another example, data (such as the output data **112**) may be received from the external computing device **116** using the second set of one or more ports. For example, output data **112** generated at least in part by the layout engine module **126** may be transferred by the proxy module **142** and received by one or more of the developer modules **140**.

In one implementation, the one or more commands **110** may be generated by one or more of the developer modules **140**. The one or more commands **110** may be configured to control at least a portion of the execution of the remote application under test **124** which is configured to execute on the computing device **116**. For example, the automated test module **150** may generate commands **110** which are configured to set one or more parameters for testing, such a network address indicative of a location from which to retrieve a list of portion of the remote application under test **124**. Continuing the example, the network address may comprise a URL which is associated with the remote application under test **124** comprising one or more webpages. The one or more commands **110** may be provided to the external computing device **116** using the second set of one or more ports. For example, the one or more commands **110** may be sent to the com.apple.webinspector service executing on the external computing device **116** within the iOS® operating system.

In some implementation the developer module **140** may use the proxy module **142**, the driver module **144**, or both for automated testing. In this implementation, the developer module **140** may access an automated test script, such as the automated test script data **322**. Once accessed, the developer module **140** may generate or replay the one or more commands **110** based on the automated test script. For example, the automated test module **150** may access the test script data **322** and begin executing the script.

As described elsewhere in this disclosure, the proxy module **142** may receive commands **110** from the driver module **144**. For example, as described elsewhere in this disclosure, the driver module **144** may convert the commands **110** from a first form to a second form. The proxy module **142** may then pass those commands **110** which are now in the second form to the computing device **116**.

In one implementation, the commands **110** may be compliant with at least a portion of remote debugging protocol as promulgated by Google Inc. of Mountain View, Calif. The external computing device **116** may execute the iOS® operating system version 7.0 or higher as promulgated by Apple Corp. of Cupertino, Calif. In this implementation, the proxy module **142** serves to connect the developer modules **140** which use the remote debugging protocol and one or more modules executing in the iOS® operating system, such as the com.apple.webinspector, WebKit®, and so forth.

As described elsewhere in this disclosure, such as with regard to FIG. 8, the commands **110** may be converted from a first form to a second form. In one implementation, prior to providing the commands **110**, the driver module **144** may convert the one or more commands **110** provided to the external computing device to one or more expressions configured to control operation of a WebKit® layout engine module **126**.

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Other commands **110** may also be transferred by the proxy module **142**. In one implementation at least a portion of the one or more commands **110** may be configured to clear a browser cache (or other cache) associated with the layout engine module **126**. In this implementation, as described elsewhere in this application, MacFUSE may be used to access the app container of the remote application under test **124** to delete files such as those stored within the cache.

FIG. **8** depicts a flow diagram **800** of the driver module **144** converting commands from a first form to a second form. In some implementations, "form" may refer to a format, syntax, grammar, or other mechanism to structure a command **110**. For example, the first form may comprise a command **110** which is compliant with the remote debugging protocol, while the second form of the same command **110** may be expressed as an application call to a WebKit® interface.

Block **802** receives one or more commands **110** expressed in a first form. While in the first form, the command **110** may be inoperable to control the layout engine module **126** of one or more of the computing device **116**. For example, the first form of the command **110** may be unrecognized by the layout engine module **126**.

Block **804** converts the command **110** from the first form to a second form, wherein the layout engine **126** is controllable by the second form. For example, the conversion may change a remote debugging protocol command **110** to a WebKit® call.

Block **806** provides the second form of the command **110** to the layout engine module **126** on the computing device **116**. For example, the driver module **144** may use the proxy module **142** to send the second form of the command **110** to the layout engine **126**.

In one implementation the second form of the command **110** may be received at a first set of one or more WebSocket ports. Communication may be established with the computing device **116** at a second set of one or more WebSocket ports. The second form of the command **110** may be sent to the layout engine module **126** using the second set of one or more WebSocket ports. The driver module **144** provides the capability for the developer modules **140**, which may not otherwise be compatible, to operate the layout engine module **126** or other services or modules provided by the computing device **116**.

FIG. **9** depicts a flow diagram **900** of debugging a markup language application **108** using the proxy module **142**.

Block **902** executes a proxy module **142**. As described in this disclosure, in one implementation the proxy module **142** may provide a first set of WebSockets and a second set of WebSockets, and allow transfer of data between the first and second sets.

Block **904** executes one or more developer modules **140**. The developer modules **140** may be configured to operate in remote application under test **124** which executes on the computing device **116**.

Block **906** establishes a connection between the developer module **140** and the remote application under test **124** using the proxy module **142**. For example, the debug module **148** may establish a WebSockets connection with the first set of WebSockets provided by the proxy module **142**.

Block **908** starts video capture on the computing device **116**. For example, a video capture application executing on the computing device **116** may be executed. The video capture may be implemented as described in U.S. patent application Ser. No. 13/619,867, filed on Sep. 14, 2012, titled "Remote Control of a Mobile Device" to Manish Lachwani, et al. which has been incorporated by reference into this disclosure.

Block **910** sends one or more commands **110** from the developer module **140** to the remote application under test **124** using the proxy module **142**. As described above, in some

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implementations the driver module **144** may be used to convert at least a portion of the commands **110** from a first form to a second form, wherein the second form is operable with regard to the remote application under test **124**, or one or more modules executing on the computing device **16**.

Block **912** stops video capture on the computing device. For example, the video capture application may be terminated or suspended.

Block **914** receives output data **112** from the computing device **116**. For example, the layout engine module **126** may provide output data **112** from the com.apple.webinspectord daemon.

Block **916** generates session data **114** based at least in part on the output data **112**. For example, the session data **114** may comprise a JSON file.

Illustrative Code

For illustration, and not by way of limitation, the following examples of illustrative code are provided.

Code Sample 1: Proxy module **142** establishes communication with computing device **116** and sets up web inspector.

```
// get phone
if (IDevice_E_SUCCESS != idevice_new(&phone, device_id)) {
    perror("No iPhone found, is it plugged in?");
    goto cleanup;
}
// connect to lockdown
if (LOCKDOWN_E_SUCCESS !=
lockdown_client_new_with_handshake(
    phone, &client, "Chrome_iOS_webkit_inspector")) {
    printf("Could not connect to lockdown. Exiting.");
    goto cleanup;
}
// connect to webinspector
if (idevice_connect(phone, service->port, &Connection)) {
    printf("idevice_connect failed!");
    goto cleanup;
}
// start webinspector, get port
if ( (lockdown_start_service(client,
"com.apple.webinspector", &service) !=LOCKDOWN_E_SUCCESS)
||
    !service) {
    printf("Could not start com.apple.webinspector!");
    goto cleanup;
}
```

Code Sample 2: Proxy module **142** disconnects from web inspector executing on the computing device **116**.

```
// disconnect
idevice_disconnect(connection);
free(connection);
lockdown_client_free(client);
idevice_free(phone);
```

WebSocket OPCODES supported by the proxy module **142**:

#defineOP_CODE_CONTINUATION	0x0
#defineOP_CODE_TEXT	0x1
#defineOP_CODE_BINARY	0x2
#defineOP_CODE_CLOSE	0x8
#defineOP_CODE_PING	0x9
#defineOP_CODE_PONG	0xA

Code Sample 3: Defining the WebSocket structure which includes API and callbacks.

```
struct websocket_struct {
    //
    // Use these APIs:
```

```
//
websocket_status (*on_recv)(websocket_t self, const char
*buf, ssize_t length);
websocket_status (*send_connect)(websocket_t self,
    const char *resource, const char *protocol,
    const char *host, const char *origin);
websocket_status (*send_upgrade)(websocket_t self);
websocket_status (*send_frame)(websocket_t self,
    bool is_fin, websocket_opcode opcode, bool
is_masking,
    const char *payload_data, size_t payload_length);
websocket_status (*send_close)(websocket_t self,
websocket_close close_code,
    const char *reason);
void *state;
bool *is_debug;
//
// Set these callbacks:
//
websocket_status (*send_data) (websocket_t self,
    const char *data, size_t length);
websocket_status (*on_http_request)(websocket_t self,
    const char *method, const char *resource, const
char *version,
    const char *headers, size_t headers_length,
    bool is_websocket, bool *to_keep_alive);
websocket_status (*on_upgrade)(websocket_t self,
    const char *resource, const char *protocol,
    int version, const char *sec_key);
websocket_status (*on_frame)(websocket_t self,
    bool is_fin, websocket_opcode opcode, bool
is_masking,
    const char *payload_data, size_t payload_length,
    bool *to_keep);
// For internal private use only:
websocket_status (*on_error)(websocket_t self, const char
*format, ...);
    websocket_private_t private_state;
};
// Create a webinspector connection.
//
// @param deviceid iOS 40-character device id, or NULL for
any device
// @param to_deviceid selected device_id (copy of device_id
if set)
// @param to_devicename selected device name
// @param recv_timeout Set the socket receive timeout for
future receive calls:
// negative for non-blocking,
// zero for the system default (5000 millis), or
// positive for milliseconds.
// @result fd, or -1 for error
int webinspector_connect(const char *deviceid, char
**to_deviceid,
    char **to_devicename, int recv_timeout);
struct webinspector_app_struct {
    char *app_id;
    char *app_name;
};
bool is_proxy;
typedef struct webinspector_app_struct *webinspector_app_t;
struct webinspector_page_structf
    uint32_t page_id;
    char *connection_id;
    char *title;
    char *url;
};
typedef struct webinspector_page_struct
*webinspector_page_t;
```

Code Sample 4: iOS® webinspector struct which defines API and callbacks

```
// iOS WebInspector.
struct webinspector_struct {
    //
    // Use these APIs:
```

```
//
webinspector_status (*on_recv)(webinspector_t self,
const char *buf, ssize_t length);
5 webinspector_status
(*send_reportIdentifier)(webinspector_t self,
    const char *connection_id);
webinspector_status
(*send_getConnectedApplications)(webinspector_t self,
    const char *connection_id);
10 webinspector_status
(*send_forwardGetListing)(webinspector_t self,
    const char *connection_id, const char *app_id);
webinspector_status
(*send_forwardIndicateWebView)(webinspector_t self,
    const char *connection_id, const char *app_id,
15 uint32_t page_id, bool is_enabled);
webinspector_status
(*send_forwardSocketSetup) (webinspector_t self,
    const char *connection_id, const char *app_id,
    uint32_t page_id, const char *sender_id);
webinspector_status
20 (*send_forwardSocketData)(webinspector_t self,
    const char *connection_id, const char *app_id,
    uint32_t page_id, const char *sender_id,
    const char *data, size_t length);
webinspector_status
(*send_forwardDidClose)(webinspector_t self,
    const char *connection_id, const char *app_id,
25 uint32_t page_id, const char *sender_id);
void *state;
bool *is_debug;
//
// Set these callbacks:
//
30 webinspector_status (*send_packet)(webinspector_t self,
const char *packet, size_t length);
webinspector_status (*on_reportSetup)(webinspector_t
self);
webinspector_status
(*on_reportConnectedApplicationList)(webinspector_t self,
35 const webinspector_app_t *apps);
webinspector_status
(*on_applicationConnected) (webinspector_t self,
    const webinspector_app_t app);
webinspector_status
(*on_applicationDisconnected)(webinspector_t self,
    const webinspector_app_t app);
40 webinspector_status
(*on_applicationSentListing)(webinspector_t self,
    const char *app_id, const webinspector_page_t
*pages);
webinspector_status
(*on_applicationSentData)(webinspector_t self,
45 const char *app_id, const char *dest_id,
    const char *data, size_t length);
// For internal use only:
webinspector_status (*on_error) (webinspector_t self,
const char *format, ...);
    webinspector_private_t private_state;
```

Proxy module 142 (Chrome_iOS_webkit_inspector) exemplary command line options:

```
55 # Chrome_iOS_webkit_inspector -h
Usage: Chrome_iOS_webkit_inspector [OPTIONS]
iOS WebKit Remote Debugging Protocol Proxy.
    -c, --config CSV [UDID]:port[-port]config(s),
defaults to:
    null:9221,:9222-9322
60 which will list devices on port 9221 and assign
all other devices (":") to the next unused port in
the
    9222-9322 range.
    E.g. to track a single device with a specific port:
        5ee0e410c6c6ac2de1a8475fc270afea197bbe40:9223
65 The value can be the path to a file in the above
format.
```

-continued

```

-f, --frontend URL    Developer Tools frontend UI path or
URL, defaults to:
    http://chrome-devtools-
frontend.appspot.com/static/18.0.1025.74/devtools.html
E.g. to use a local WebKit checkout:
    /usr/local/WebCore/inspector/front-
end/inspector.html
E.g. to use a remote server:
    http://foo.com:1234/bar/inspector.html
The value must end in ".html"
--no-frontend    Disable the Developer Tools frontend.
-d, --debug    Enable debug output.
-h, --help    Print this usage information.

```

Those having ordinary skill in the art will readily recognize 15
that certain steps or operations illustrated in the figures above
may be eliminated, combined, or performed in an alternate
order. Any steps or operations may be performed serially or in
parallel. Moreover, the methods described above may be
implemented as one or more software programs for a com- 20
puter system and may be encoded in a computer-readable
storage medium as instructions executable on one or more
processors.

Embodiments may be provided as a computer program 25
product including a non-transitory computer-readable stor-
age medium having stored thereon instructions (in com-
pressed or uncompressed form) that may be used to program
a computer (or other electronic device) to perform processes
or methods described herein. The computer-readable storage 30
medium may be one or more of an electronic storage medium,
a magnetic storage medium, an optical storage medium, a
quantum storage medium, and so forth. For example, the
computer-readable storage media may include, but is not
limited to, hard drives, floppy diskettes, optical disks, read- 35
only memories (ROMs), random access memories (RAMs),
erasable programmable ROMs (EPROMs), electrically eras-
able programmable ROMs (EEPROMs), flash memory, mag-
netic or optical cards, solid-state memory devices, or other
types of physical media suitable for storing electronic instruc- 40
tions. Further, embodiments may also be provided as a com-
puter program product including a transitory machine-read-
able signal (in compressed or uncompressed form). Examples
of machine-readable signals, whether modulated using a car- 45
rier or unmodulated, include but are not limited to signals that
a computer system or machine hosting or running a computer
program can be configured to access, including signals trans-
ferred by one or more networks. For example, the transitory
machine-readable signal may comprise transmission of soft- 50
ware by the Internet.

Separate instances of these programs can be executed on or
distributed across any number of separate computer systems.
Thus, although certain steps have been described as being
performed by certain devices, software programs, processes, 55
or entities, this need not be the case and a variety of alternative
implementations will be understood by those having ordinary
skill in the art.

Additionally, those having ordinary skill in the art readily
recognize that the techniques described above can be utilized 60
in a variety of devices, environments, and situations.
Although the present disclosure is written with respect to
specific embodiments and implementations, various changes
and modifications may be suggested to one skilled in the art.
It is intended that the present disclosure encompass such 65
changes and modifications that fall within the scope of the
appended claims.

What is claimed is:

1. A system comprising:

at least one processor;

at least one memory coupled to the at least one processor
and storing instructions that, when executed on the at
least one processor, cause the system to perform func-
tions comprising:

receiving one or more first-form commands in a first
form which is compliant with a remote debugging
protocol and wherein the first form is incompatible
with a layout engine;

converting the one or more first-form commands to one
or more second-form commands in a second form,
wherein the second form is compatible with at least a
portion of the layout engine, and wherein the layout
engine is configured to execute a markup language
application that includes one or more instructions
expressed in a markup language;

providing the one or more second-form commands com-
patible with the layout engine; and

after providing the one or more second-form commands,
receiving output data resulting from execution of the
markup language application by the layout engine.

2. The system of claim 1, wherein the markup language
comprises a hypertext markup language ("HTML").

3. The system of claim 1, wherein the functions further
comprise:

transferring data using the system, wherein the data com-
prises one or more of: at least one of the one or more
first-form commands, at least one of the one or more
second-form commands, and at least a portion of the
output data.

4. The system of claim 1, wherein at least one first-form
command of the one or more first-form commands is config- 35
ured to clear a browser cache associated with the layout
engine.

5. The system of claim 1 wherein the functions further
comprise:

providing session data related to the one or more first-form
commands.

6. The system of claim 1, wherein:

the layout engine comprises one or more embedded test
tools providing functionality for testing the layout
engine; and

the remote debugging protocol is compliant with a prede- 45
termined remote debugging protocol.

7. The system of claim 1, further wherein the layout engine
is configured to operate within an operating system having a
secured configuration.

8. The system of claim 1, wherein the layout engine com- 50
prises one or more embedded test tools providing function-
ality for testing the layout engine, and wherein the one or
more second-form commands comprises a second-form com-
mand that is compatible with the one or more embedded test
tools.

9. The system of claim 1, wherein:

the one or more commands in the first form, the second
form, or both are included in an automated test script.

10. A computer-implemented method, comprising:

receiving one or more first-form commands in a first form
that is compliant with a remote debugging protocol and
wherein the first form is incompatible with a layout
engine;

converting the one or more first-form commands to one or
more second-form commands in a second form, wherein
the second form is compatible with at least a portion of
the layout engine, and wherein the one or more second-

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form commands are configured to control at least a portion of execution of a remote application under test executing on a computing device, wherein the remote application under test is expressed at least in part using a markup language;

establishing communication using a set of one or more ports;

providing the one or more second-form commands using the set of one or more ports; and

after providing the one or more second-form commands receiving output data resulting from execution of the remote application under test using the set of one or more ports.

11. The method of claim **10**, wherein at least a portion of the one or more second-form commands specify a network address indicative of a location from which to retrieve at least a portion of the remote application under test, the remote application under test comprising one or more web pages.

12. The method of claim **10**, wherein the one or more second-form commands comprises a second-form command that is compatible with one or more embedded test tools.

13. The method of claim **12**, wherein the one or more embedded test tools provide functionality for testing a layout engine that is configured to render the markup language.

14. The method of claim **10**, wherein at least one port set of one or more ports are compliant with a predetermined communication protocol.

15. The method of claim **10**, wherein establishing communication using the set of ports comprises:
initiating a connection via a universal serial bus.

16. A method, comprising:

receiving one or more first-form commands expressed in a first form at a computing device, wherein the first form is

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compliant with a remote debugging protocol, and wherein the first form is incompatible with a layout engine;

converting the one or more first-form commands to one or more second-form commands in a second form using the computing device, wherein the second form is compatible with at least a portion of the layout engine, and wherein the layout engine is configured to execute a markup language application that includes one or more instructions expressed in a markup language;

providing the one or more second-form commands second form to the first layout engine; and

after providing the one or more second-form commands, receiving output data resulting from execution of the markup language application by the layout engine.

17. The method of claim **16**, wherein the one or more commands in the first form, the second form, or both are included in an automated test script data.

18. The method of claim **16**, wherein:

the layout engine comprises one or more embedded test tools providing functionality for testing the layout engine.

19. The method of claim **16**, wherein the application comprises one or more web pages and the one or more first-form commands comprise at least one command configured to designate a network address associated with assess one or more web pages.

20. The method of claim **16**, wherein providing the command in the second form of the command comprises establishing communication with the external computing device using a set of one or more ports; and sending the second form of the command to the external computing device using the set of one or more ports.

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